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LABORATORI NAZIONALI di LEGNARO

INTRODUCTION

The 1984 has been the first year of full operation of the XTU Tandem accelerator for routinely planned experiments in nuclear physics.

The Tandem has operated at an average voltage of ∿13 MV; a very large variety of beams ranging from proton up to bromine has been accelerated. The largest fraction of the research program has been done with heavy ions (A⩾12, typically Si, S). Interesting and successful experiments were performed in the fields of nuclear structure and reaction mechanisms; some promising work in ultrasensitive Tandem mass spectrometry has also been started. More than 15 research groups have alternated and sometimes crowded around the accelerator.

In parallel the beam time request at the small Van de Graaff accelerators (7 MV - CN and 2 MV) has increased. This shows an increasing interest in the fields of applied nuclear physics work in biophysics, solid state, neutron dosimetry, environmental researches.

Two successful meetings were organized at the Laboratories: "*Three-day in depth review on the nuclear accelerator impact in the interdisciplinary field*" (May 30 - June 1, 1984) and "*ESONE CAD Seminar, General Assembly and CAD exhibition*" (September 26-28, 1984).

Prof. Cosimo Signorini
Director

- CONTENTS -

EXPERIMENTAL NUCLEAR PHYSICS

THEORETICAL NUCLEAR PHYSICS

APPLIED NUCLEAR PHYSICS

NEW EXPERIMENTAL FACILITIES

TECHNICAL DEVELOPMENTS

ACCELERATORS

- EXPERIMENTAL NUCLEAR PHYSICS -

APPLICATION OF THE TRANSIENT MAGNETIC FIELD TO THE g-FACTOR MEASUREMENT OF THE LOWEST $3/2^-$ AND $5/2^-$ STATES IN ^{107}Ag AND ^{109}Ag

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The transient magnetic field (TF) experienced by swift nuclei recoiling in saturated ferromagnetic media has found a very remarkable application in the measurement of the magnetic moment of excited nuclear states[1].

In the present work we consider the lowest $3/2^-$ and $5/2^-$ states in ^{107}Ag and ^{109}Ag which were Coulomb excited with a 90 MeV ^{32}S beam from the XTU Tandem accelerator of the L.N.L.. The silver targets consisted of 600 μg/cm² of ^{107}Ag and ^{109}Ag evaporated on 2.2 mg/cm² of iron backed with 3.5 mg/cm² of copper. The gamma rays from the investigated states were detected with four 4"×4" NaI detectors in coincidence with backscattered ^{32}S ions detected in an annular parallel plate avalanche counter (PPAC).

The PPAC has a dimension of 4 cm × 4 cm and a 3 mm central hole; the entrance window was a 2 μm thick macrofol foil (Bayer), the pressure of the isobutilene gas was 10 mbar and the operating voltage was 450 volts.

The entrance and exit velocities of the recoiling silver nuclei in the iron foil ($v_{in}=4.4v_0$ and $v_{out}=2.0v_0$ with $v_0=c/137$) were deduced from the kinematic of the reaction assuming the Ziegler stopping powers[2].

A sketch of the scattering chamber used in the measurement reported here is shown in fig. 1. The thermal contacts were improved by directly screwing the sandwich target between the pole tips of the electromagnet with a copper frame. The gamma detectors were located on a turnable table at a distance of 16 cm from the target. Two detectors were positioned at ±42° and the other two at ±112° with respect to the beam direction, in order to get a good sensitivity for the dipole $3/2^- \rightarrow 1/2^-$ and quadrupole $5/2^- \rightarrow 1/2^-$ transitions, respectively.

Furthermore a germanium detector was positioned at 15° for monitoring the adherence of the target layers. An external field of only 0.012 T saturated the iron foils to more than 90% as was checked with a high sensitivity induction coil magnetometer. With such a low field beam bending effects were negligible. The direction of the magnetisation was reversed about every 2 minutes, at prefixed integral counts in the PPAC, in order to reduce possible systematic errors.

The observed effects for a pair of symmetrical detectors, usually defined as

$$\varepsilon=\frac{\sqrt{r}-1}{\sqrt{r}+1} \quad \text{with} \quad r=\frac{N_+^{\uparrow}N_-^{\downarrow}}{N_+^{\downarrow}N_-^{\uparrow}}$$

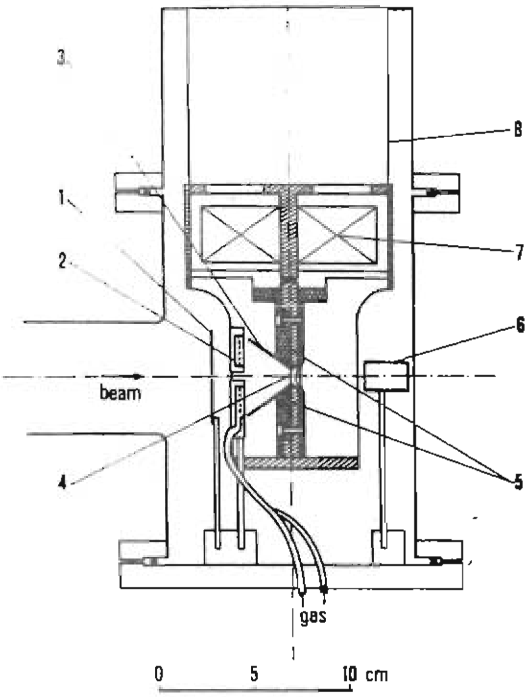

Fig. 1. - Sketch of the scattering chamber. The numbers denote the following: 1) 2 mm diaphragm, 2) PPAC, 3) soft iron snout, 4) sandwich target, 5) pole tips, 6) Faraday cup, 7) coil, 8) LN_2 container.

were compared with those obtained by a ±2° rotation of the turn able table sustaining the NaI detectors.

Since for small angles the approximation $\varepsilon = S \cdot \Delta\Theta$ holds (where $S = \frac{1}{W}\frac{dW}{d\Theta}$ is the slope of the angular distribution) one can easily deduce the angular precession due to the transient field.

If, as in our case, the lifetime of the investigated states is longer than one picosecond, the angular precession is related to the TF by the expression

$$\Delta\Theta \sim g \frac{N}{h} \int_{t_{in}}^{t_{out}} B_{TF}(t)dt.$$

Up to now no quantitative prediction for the intensity of the TF exists.

As a consequence, under the assumption that the TF is similar for neighbouring atomic numbers, we could get absolute g-factor values after comparison with the precession observed in similar conditions in ^{106}Pd where for the first 2^+ state g=0.40 (2) is known[3).

The experimental data and results are summarized in table and the obtained g-factors agree with the prediction of the Interacting Boson Fermion Model (IBFM).

The mean transient field observed in the present experiment was of the order of 1.5 KT.

According to more detailed studies[1], the velocity dependence of the TF can be approximated by the empirical expression

$$B_{TF}=\alpha \cdot z^{1.1} \cdot v^{0.45}/v_0 \text{ kT}.$$

From the present study we deduced $\alpha=14.1$ for the case of the investigated nuclei.

TABLE

Nucleus	I	E_x (MeV)	$\Delta\Theta$ (mr)	g
^{107}Ag	$3/2^-$	325	19.7 (23)	0.70 (9)
	$5/2^-$	423	12.8 (16)	0.45 (6)
^{109}Ag	$3/2^-$	311	22.9 (24)	0.79 (12)
	$5/2^-$	415	10.7 (14)	0.36 (6)
^{106}Pd	2^+	512	12.6 (9)	

References

(1) M. Benczer-Koller, M. Hass and J. Sak, Ann. Rev. Nucl. Part. Sci. 30 (1980) 53.

(2) J.F. Ziegler, Appl. Phys. Lett. 31 (1977) 544.

(3) J.M. Brennan, M. Haas, N.K.B. Shu and N. Benczer-Koller, Phys. Rev. C21 (1980) 574 and references therein.

TRANSIENT MAGNETIC FIELD FOR SILICON IN IRON AND GADOLINIUM AT A VELOCITY OF 7.5 v_0

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A recent measurement (1) at a recoil velocity of 7 v_0 (v_0=c/137) has shown that for oxygen the transient magnetic field (B_{TF}) is 2.3 times stronger in gadolinium than in iron. This finding is in contrast to the scaling of B_{TF} with the electron polarization density (which is similar for these ferromagnets) as observed at lower recoil velocities.

We have therefore investigated the case of silicon recoiling into iron and gadolinium with the purpose of looking for a similar effect, which would strongly favour the use of gadolinium as ferromagnet in transient field measurements.

We used the inverse reaction $^4He(^{28}Si,\alpha)$ at 83.2 MeV in correspondence to the prolific 11.65 MeV resonance in the direct reaction. The 1779 keV gamma rays, depopulating the first 2^+ state in ^{28}Si (τ=700 fs, g=0.53) were detected by four NaI 10.2 cm × 10.2 cm located at ±68° and ±112° at a distance of 16 cm from the target. Moreover a germanium detector was positioned at 15° in order to check the layer adherence.

The gamma rays were recorded in coincidence with alphas detected in forward direction by a surface barrier Si detector. In the iron experiment a 80 nA beam impinged on an annealed 1.3 mg/cm² thick iron foil, implanted with 6×10^{17} at/cm² helium at 40 keV. The foil was backed by 5.8 mg cm² of evaporated Ag.

In the gadolinium experiment a 30 nA beam was sent on an annealed 2.5 mg/cm² Gd, implanted with 10^{16} at/cm² helium at 40 keV and backed with 10 mg/cm² Ag. The mean entrance velocity was 8.2 v_0 while the exit velocity was 6.9 v_0.

The targets were cooled with a liquid nitrogen cryostat. The experimental procedure is similar to that reported in ref.2.

Preliminary results are summarized in table.

host	$\bar{v}/v_0$	t_{eff}(fs)	$\Delta\theta$(mrad)	B_{eff}(T)
Fe	7.5	74	3.4 (7)	1835(380)
Gd	7.5	143	5.0(10)	1610(380)

No enhancement of B_{TF}(Gd) over B_{TF}(Fe) has been observed. Further measurements are planed in order to increase the reliability of the data and to get information at higher recoil velocity.

References

(1) K.H. Speidel, F. Hagelberg, M. Knopp, W. Trölenberg and H. Neuburger; to be published.
(2) D. Bazzacco, F. Brandolini, P. Pavan, C. Rossi Alvarez, R. Zannoni and M. de Poli; contribution to this report.

TRANSIENT MAGNETIC FIELD FOR NEON AND SILICON IN GADOLINIUM AT A VELOCITY OF $2v_0$

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In transient magnetic field measurements, gadolinium can be a more convenient ferromagnet than iron, since it gives rise (for not shortliving states) to bigger effects. In fact in both ferromagnets the transient field has nearly the same strength at low recoil velocities but the stopping power dE/dx for gadolinium is about two times smaller: i.e., for a given energy loss, the transit time is correspondingly increased.

The functional dependence of the magnetic transient field B_{TF} on the velocity v and on the atomic number Z_1 and Z_2 is not yet well understood. In particulat the low velocity data are rather scanty for light nuclei (1). Furthermore they were mainly obtained with a thick gadolinium backing, which leads to several difficulties in the interpretation of the data. Neon and silicon have been chosen as first candidates to be investigated at the CN accelerator, since they previously have been studied in iron. The experimental set-up was similar to that reported elsewhere in this report (2).

In the case of neon the reaction $^{19}F(\alpha,p)^{22}Ne$ at 8.05 MeV has been used to populate the 2^+ state at 1275 keV (τ=5.2 ps, g=0.33). The target consisted of 150 μg/cm² of LiF on a 1.1 mg/cm² Gd layer, backed with 1.5 mg/cm² of evaporated gold.

In the case of silicon the reaction $^{28}Si(\alpha,\alpha')$ at 11.65 MeV was used to populate the 2^+ state at 1779 keV (τ=700 fs, g=0.53). The target consisted of 100 μg/cm² of Si on a 1.15 mg/cm² Gd layer backed with 2 mg/cm² gold.

The observed precession of the angular distribution $\Delta\theta$ is related to the effective field B_{eff} by the formula $\Delta\theta = g \cdot \mu/\hbar \cdot B_{eff} \cdot t_{eff}$, where the effective time t_{eff} takes into account the effect of the lifetime of the state on the transit time.

Beam bending effects were measured and found to be negligible. The results are summarized in the table.

nucleus	v_{in}/v_0	v_{out}/v_0	t_{eff}(fs)	$\Delta\theta$(mrad)	B_{eff}(KT)
^{22}Ne	1.8	0.9	460	1.6 (3)	260
^{28}Si	2.4	1.2	294	2.45(15)	430

Together with the high velocity data the observed transient fields can be described by a linear expression of the form $B_{TF}=17 \cdot Z \cdot v/v_0$ (Tesla).

More experimental information is desirable in order to complete the overall picture.

References

(1) K.H. Speidel, P.N. Tandon and V. Mertens; Z. Phys. A302 (1981) 107 and references therein.
(2) D. Bazzacco, F. Brandolini, P. Pavan, C. Rossi Alvarez, R. Zannoni, M. de Poli; contribution to this report.
(3) K.H. Speidel, P.N. Tandon and V. Mertens, W. Trölenberg, G.J. Kumbartzki, N. Ayres de Campos and B. Goldberg; Nucl. Phys. A378 (1982) 130.

BACKWARD ANGLES RESONANCES IN THE YIELD OF THE (α,α') AND (α,p) REACTIONS FOR THE NUCLEI ^{20}Ne,^{24}Mg,^{28}Si,^{32}S

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The reactions (α,α') and (α,p) on light even-even nuclei can be a very convenient mean to populate states, to be used as probes in transient field measurements. In fact the residual nucleus, corresponding to a light particle detected at backward angles, is fully aligned, which is a determinant advantage when measuring integral angular precession.

On the other hand, since the differential cross-section, at backward angles strongly fluctuate as function of the beam energy, it is convenient to look for suitable resonances.

As first candidates we have selected the self conjugated nuclei ^{20}Ne, ^{24}Mg, ^{28}Si, ^{32}S for which the (α,α') cross-section is particularly strong. We have measured the population of the first 2^+ and 4^+ states in (α,α') and, in the case of ^{28}Si, also the (α,p) yield to the lowest $3/2^+$ and $5/2^+$ in ^{31}P.

The measurements have been performed at the CN accelerator using a doubly charged alpha beam of about 20 nA. The yields were measured in the energy range 8-14 MeV in steps of 30 keV.

The particle detector was an annular surface barrier Si detector with an area of 300 mm² and a thickness of 300 μm located at backward angles at a distance of 2.5 cm from the target.

In order to be able to reduce contamination effects and to discriminate between alphas and protons, the particles were taken in coincidence with four NaI detectors placed at ±45° and ±135° and at 10 cm from the target.

The coincidence data were recorded in list mode on magnetic tape as 4 triparametric events using the SADIC acquisition system. The data were then analysed off line.

The ^{20}Na target was prepared at the Catania Department of Physics by implanting $3x10^{17}$ at/cm² ^{20}Ne at 100 KV on a 2.3 mg/cm² Ta foil at liquid nitrogen temperature. The other used targets were as following: 50 μg/cm² natural magnesium on 2.3 mg/cm² Ta; 65 μg/cm² natural silicon on 20 μg/cm² C; 100 μmcm² natural sulphur on 2.3 mg/cm² Ta.

The yield measurement was greatly simplified by a semiautomatic procedure, which also writes on the tape the N.M.R. frequency associated to the point. A typical partial yield is shown in Fig. 1. The highest point corresponds to a cross section of about 100 mb/sr.

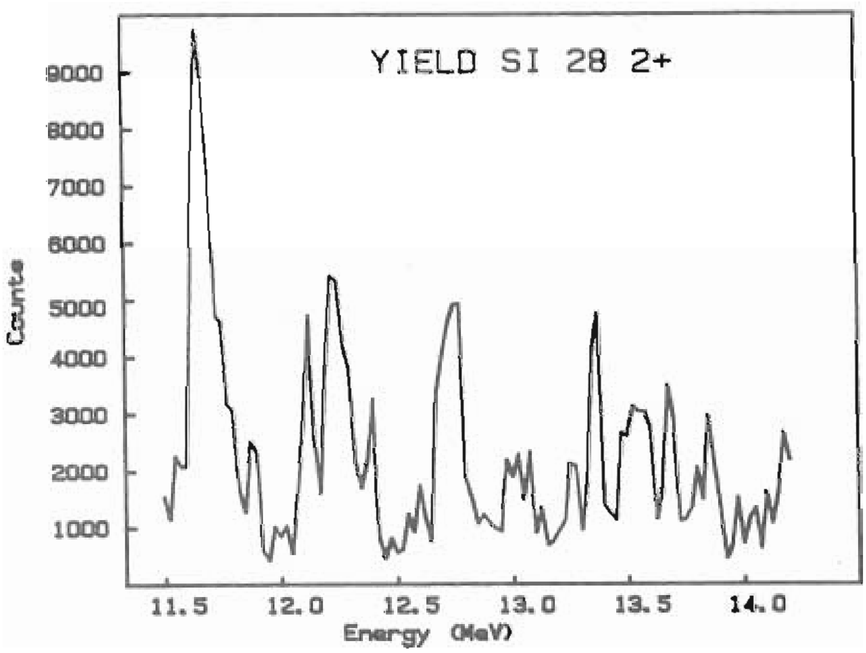

Fig. 1. Alphas yield as observed in $^{28}Si(\alpha,\alpha')$ for the first 2^+ state.

HIGH SPIN STATES IN ^{98}TC

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As a part of a systematic investigation of nuclei with Z = 40-50 ($g_{9/2}$ proton shell) the high spin states of ^{98}Tc have been investigated via the reaction ^{94}Zr(^{7}Li, 3n) ^{98}Tc by in beam γ spectroscopy measurements. Previous studies on this nucleus have been carried out by our group [1)] and by other authors [2,3)] mainly via the (p,n) reaction and only levels with J $\leq$ 7 have been observed up to 714 keV excitation energy.

In the present experiment the ^{7}Li beam of the Tandem XTU of Laboratori Nazionali di Legnaro has been used to bombard a self supporting ^{94}Zr target (618 μg/cm^{2} thick; 91.2 % enriched) in order to populate the high spin states of ^{98}Tc. Behind the ^{94}Zr target a thick ^{208}Pb layer (99.0 % enriched) was placed as beam stopper.

Gamma rays have been detected by three coaxial Ge(Li) detectors with 18% efficiency and ~ 2 keV resolution at 1170 keV, placed at -90°, 0° and + 90° respectively to the beam direction.

A typical γ spectrum is shown in fig.1.

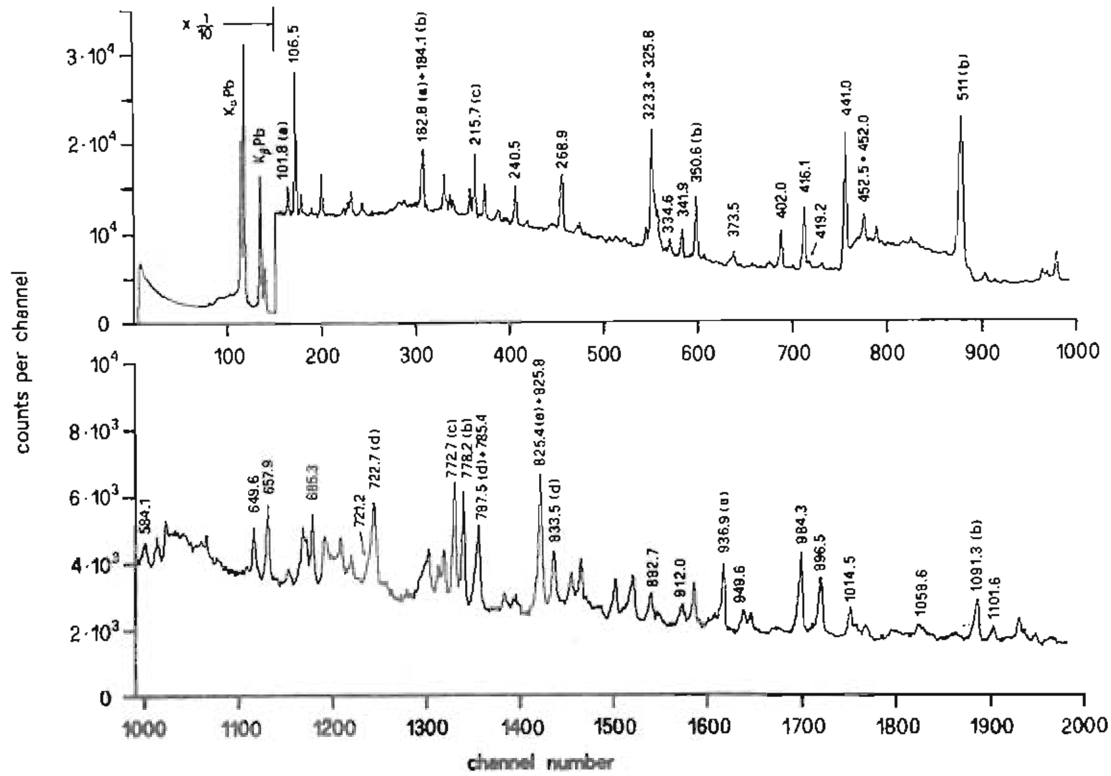

Fig. 1 - Singles γ-scpectrum from ^{94}Zr + ^{7}Li reaction at E(^{7}Li) = 26.5 MeV and ϑ = 90°. Energies are in KeV. Labelled peaks belong to ^{98}Tc unless otherwise specified. (a) ^{96}Nb; (b) Activation; (c) ^{97}Tc; (d) ^{98}Mo; (e) not assigned.

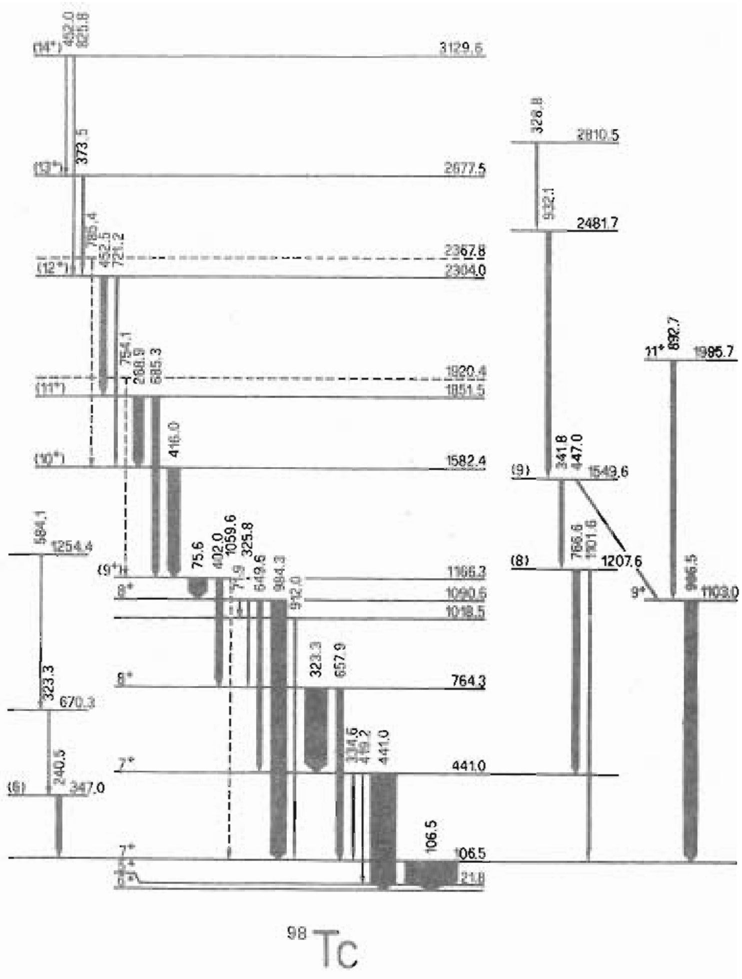

Fig. 2 - High spin level scheme of ^{98}Tc

Excitation function, $\gamma - \gamma$ coincidences and 0°-90° anisotropy have been measured for several γ transitions.

Excitation functions were obtained in the energy interval 23-31 MeV and $\gamma - \gamma$ coincidences were performed at E(^{7}Li) = 26.5 MeV in the standard three parameter mode for each detector pair.

The main results are summarized in Table I and the obtained level scheme of ^{98}Tc is shown in fig. 2.

21 new levels with high spin, up to J=14, have been observed. Spin values shown in the figure are deduced from γ ray excitation functions, 0°-90° anisotropies and relative intensities.

The J=8 state at 764.3 keV is probably the expected highest-spin member of the $\pi g_{9/2} \otimes \nu g_{7/2}$ multiplet, although its energy is larger than the value predicted on the basis of the "parabolic rule"[3].

The tentative parity assignments are based on the decay systematics. Conversion electron measurements are in progress to verify the parities of the levels.

References

1) M.Bini et al. - Phys.Rev. 18C, 108 (1978)
2) H.W.Müller - Nucl. Data Sheets, 39 467 (1983)
3) Z. Arvay et al. - Physica Scripta 26, 57 (1982)

TABLE I

E_γ (KeV)	Coincident γ - lines (KeV)
75.6	106.5, 268.9, 323.3, 325.8, 334.6, 373,5, 416.0, 441.0, 452.5, 649.6, 685.3, 754.1, 785.4, 825.8, 984.3
106.5	75.6, 240.5, 268.9, 323.3, 325.8, 328.8, 334.6, 341.9, 373.5, 402.0, 416.0, 441.0, 447.0, 452.5, 584.1, 657.9, 685.3, 721.2, 754.1, 785.4, 825.8, 892.7, 912.0, 949.6[a], 984.3, 996.5, 1014.6, (1059.6), 1101.6
240.5	(75.6), 106.5, (268.9), 323.3, (418), 584.1, 671.6[a], (685.3)
268.9	75.6, 106.5, 323.3, 402.0, 416.0, 441.0, 452.5, 825.8, 984.3
323.3[b]	75.6, 106.5, 240.5, 268.9, 325.8, 334.6, 373.5, 402.0, 416.0 419.2, 441.0, 452.5, 671.6[a], 685.3, 754.1, 785.4
325.8	75.6, 106.5, 323.3, 416.0, 441.0, 452.5, 685.3
328.8	106.5, 441.0, 932.1
334.6	106.5, 323.3
341.9	106.5, 441.0, 766.6, 932.1, 1101.6
373.5	75.6, 106.5, 268.9, 323.3, 402.0, 416.0, 441.0, 452.0, 452.5, 685.3, 721.2, 984.3
402.0	106.5, 268.9, 323.3, 373.5, 416.0, 441.0, 452.5, 657.9, 685.3, 754.1, 825.8
416.0	75.6, 106.5, 268.9, 323.3, 325.8, 373.5, 402.0, 441.0, 452.5, 649.6, 721.2, 785.4, 825.8, 984.3
419.2	323.3, 402.0
441.0	75.6, 268.9, 323.3, 325.8, 328.8, 341.9, 373.5, 402.0, 416.0, 452.5, 649.6, 685.3, 766.6, 785.4, 825.8, 932.1
452.0 452.5	75.6, 106.5, 268.9, 323.3, 325.8, 373.5, 402.0, 416.0, 441.0, 452.0[b], 452.5[c], 649.6, 685.3, 721.2[c], 825.8[d], 984.3
584.1	106.5, 240.5, 323.3
649.6	75.6, 268.9, 416.0, 441.0, 452.5, 685.3
657.9[c]	106.5, 325.8, 402.0, 416.0
671.6	106.5, 323.3
685.3	75.6, 106.5, 323.3, 334.6, 373.5, 402.0, 441.0, 452.5, 649.6, 825.8, 984.3
721.2[f]	106.5, 323.3, 416.0, 452.0
754.1	75.6, 227[a], 323.3, 402.0, 441.0
766.6	341.9, 441.0, 932.1
785.4[f]	106.5, 323.3, 416.0, 441.0
825.8[g]	106.5, 323.3, 402.0, 416.0, 441.0, 452.5, 685.3
892.7	106.5, 996.5
912.0[e]	(71.9), (75.6), 106.5, 416.0
932.1	106.5, 328.8, 341.9, 441.0
984.3	75.6, 106.5, 268.9, (373.5), 416.0, 452.5, 685.3 (754.1), (825.8)
996.5	106.5, 229, 447.0, 892.7
1101.6	106.5, 341.9

a) unattributed

b) doublet

c) in coincidence with the 452.0 KeV gamma

d) in coincidence with the 452.5 KeV gamma

e) Contribution of the ^{97}Tc overlapping line has been subtracted

f) Contribution of the ^{98}Mo overlapping line has been subtracted

g) coincident lines at 265, 376, 680, 707 and 825 KeV which don't belong to the ^{98}Tc, on the basis of their excitation fonction, are also present.

Conversion electron measurements in ^{100}Rh and ^{102}Rh

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The previous research on the level schemes of ^{100}Rh and ^{102}Rh, performed with the ^{100,102}Ru(p,n,γ)^{100,102}Rh reactions, has been extended with the measurement of electron conversion coefficients, in order to determine the multipolarity of the different transitions.

Measurements have been performed at the CN accelerator of L.N.L., at proton energies of 6 MeV (for ^{100}Rh) and 4.5 MeV (for ^{102}Rh). Electrons were deflected with the large-acceptance electron spectrometer described in ref. 1), and their energy was measured with a Silicon detector, cooled at the liquid nitrogen temperature. Gamma rays were detected with a 2 cm^3 hyperpure Ge counter.

Two preliminary runs of measurements gave the results shown in Table I.

At the low energy considered here, and for nuclei of this region, prompt γ transitions are almost pure E1 or M1. Since the corresponding electron-conversion coefficients differ by about a factor two, it is possible to distinguish between E1 and M1 also with a limited accuracy of the measurements. It was therefore possible to assign, on the basis of the present results[2]) a positive parity to the levels at 151.8 keV, 248 keV and 282 keV in ^{100}Rh and at 105.2 keV and 178.7 keV in ^{102}Rh and a negative parity to the level at 123.8 keV in ^{102}Rh.

These results confirm the tentative parity assignments made on the only basis of the level scheme[3,4]), assuming that the two almost independent γ cascades observed in ^{100}Rh and ^{102}Rh develop along level groups characterised by opposite parity.

References

1) T. Fazzini, A. Giannatiempo, P. Perego
Nucl. Instr. Meth. 123, 125 (1983)

2) A.M. Bizzeti Sona, P. Blasi, A. Passeri , A.A. Stefanini
Proc. Int. Symposium on "In beam Nuclear Spectroscopy"
Debrecen, Hungary, May 1984 - Vol. I p.141

3) A. M. Bizzeti Sona, P. Blasi, P.A. Mandò
Zeit. Phys. A311, 163 (1983)

4) A.M. Bizzeti Sona, P. Blasi, P.A. Mandò, A.A. Stefanini
Zeit. Phys. A315, 277, (1984)

TABLE I - Conversion coefficients

Transition		Level energy (KeV)		α_K X 100			Proposed
Energy	Intensity*	Initial	Final	Exp.	Calculated		Multipolarity
E_γ (keV)	I_γ	E_i	E_f		M1	E1	
^{102}Rh							
95.3	158	302.2	206.9	41 ± 11	34.4	14.6	M1
101.7	148	206.9	105.2	16 ± 3	28.7	12.2	
103.1	84	259.6	156.5		27.5	11.7	
105.2	1,000	105.2	0		26.0	11.0	E1
123.8	322	123.8	0	14.2 ± 3	16.6	6.9	M1
135.6	30	399.4	263.8	4.7 ±0.7	12.9	5.3	E1
136.7	313	178.7	41.9		12.6	5.2	
182.1	78	305.9	123.8	5.4±0.9	5.8	2.3	M1
^{100}Rh							
151.8	1,000	151.8	0	4.0±0.8	9.4	3.9	E1
173.3	419	248.0	74.8	7.7±1.5	6.6	2.6	M1
207.2	439	282.0	74.8	3.9±0.8	4.1	1.6	M1

* relative to the γ-intensity of the 105.2 keV line for ^{102}Rh γ-transitions and to that of the 151.8 KeV line for ^{100}Rh γ-transitions.

PENETRATION EFFECTS IN THE CONVERSION PROCESSES OF THE $7/2^+_1 \rightarrow 5/2^+_1$ AND $5/2^+_1 \rightarrow 1/2^+_1$ TRANSITIONS IN ^{111}CD

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Penetration effects in the conversion process of the $7/2^+ \rightarrow 5/2^+$, 171 keV and $5/2^+ \rightarrow 1/2^+$, 245 keV transition in ^{111}Cd have been studied (1). The levels of interest have been populated in the decay of ^{111}In ($T_{1/2}$ = 2.8d) produced through (p,n) reaction. The irradiation has been performed with the proton beam of the CN accelerator of the L.N.L.(E_p = 4 MeV).

Electron spectra have been analyzed by means of a magnetic transport electron spectrometer (2) [overall efficiency ~ 1%, Δ p/p = 18%] deflecting electrons onto a 500 mm^2 x 5mm Si(Li) detector (cooled to the liquid nitrogen temperature) having 3.2 keV resolution at 200 keV. Gamma spectra were simultaneously recorded on a 2 cm^3 H.P. germanium detector whose resolution was 0.7 keV at 200 keV.

From the relative intensity of the conversion lines it has been possible to deduce the following limits for the penetration parameter λ of the M1 component in the 171 keV transition and λ_1 for the E2 245 keV transition: $0 \leq \lambda(171) \leq 2.3$ and $-0.4 \leq \lambda_1(245) \leq 1.9$.

By comparing λ (171) with the values that we have recently determined for the corresponding $7/2^+ \rightarrow 5/2^+$ transitions in ^{107}Cd to ^{109}Cd, a a regular decrease in λ from ^{107}Cd to ^{111}Cd, has been found, irrespective of the M1 hindrance factor. Therefore the monotonically increasing relation given by Subba Rao (3) between penetration parameter and hindrance factor does not apply to the M1 transitions in these nuclei. As for the slightly inhibited 245 keV, E2 transition we cannot confirm the large penetration effects reported by other authors (4).

(1) A. Giannatiempo, A. Passeri and A. Perego: Z.Phys.A-Atoms and Nuclei 319(1984)153
(2) T. Fazzini, A. Giannatiempo and A. Perego: Nucl. Instrum. Methods 211(1983)125
(3) B.N. Subba Rao: Phys. Lett. 56(1975)435
(4) A.G. Troitskaya, V.M. Kartashov and G.A. Shevelev: Izv.Akad.Nauk SSSR, Ser.Fir. 45(1981)118

GAMMA DECAY AND LIFETIMES OF EXCITED LEVELS IN ^{50}TI

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Levels in ^{50}Ti have been populated via the ^{49}Ti(d,pγ) reaction by bombarding an 1 mg /cm^2 thick self-supporting enriched target of ^{49}Ti with 6 MeV deuteron beam from the CN accelerator of L.N.L. Two sets of proton-gamma coincidences have been simultaneously recorded between each of two silicon detectors (placed at $\pm$ 45° to the beam direction) and a hyperpure Ge detector (placed at 90° in the reaction plane). The data have been stored event by event on magnetic tape and analyzed off-line. A consistent decay scheme up to an excitation energy of 6.7 MeV has been established. In particular the existence of a doublet at an excitation energy of 4.172 MeV has been established exploiting the different Doppler shifts observed for the gamma rays involved in the decay. This doublet most probably corresponds to the (2^+,3^+) doublet predicted long ago by Johnstone (1). Lifetimes or lifetime limits for 14 levels have been determined. The results are summarized in Table I.

Decay scheme and lifetimes of excited levels in ^{50}Ti

Table 1. Lifetimes of levels in ^{50}Ti.

E_{level}(keV)	E_γ(keV)	$F(\tau)$	τ(fs)
4146.9 ± 0.3	1472.1 ± 0.2	0.70 ± 0.03	48^{+10}_{-7}
4171.8 ± 0.3	1497.1 ± 0.2	0.04 ± 0.04	> 1200
	2618.0 ± 0.3	0.04 ± 0.04	
4172.3 ± 0.5	2618.6 ± 0.4	0.93 ± 0.04	< 16
4789 ± 1	3235 ± 1	0.93 ± 0.07	< 20
4880.5 ± 0.3	1682.3 ± 0.4	0.18 ± 0.07	310^{+65}_{-50}
	2205.6 ± 0.3	0.25 ± 0.03	
5185.6 ± 0.4	2510.8 ± 0.3	0.96 ± 0.04	< 10
	3631 ± 1	1.11 ± 0.15	
5379.5 ± 0.3	1207.7 ± 0.3	0.58 ± 0.10	47^{+12}_{-10}
	2704.8 ± 0.4	0.74 ± 0.05	
5836.9 ± 0.7	1690.0 ± 0.7	0.76 ± 0.20	37^{+27}_{-20}
	3162 ± 1	0.76 ± 0.15	
5945.9 ± 0.5	760.5 ± 0.4	0.64 ± 0.20	27^{+7}_{-6}
	3270.5 ± 1	0.84 ± 0.03	
	3270.5(SE)†	0.81 ± 0.09	
	3270.5(DE)†	0.84 ± 0.10	
6122.9 ± 0.4	1242.4 ± 0.2	0.66 ± 0.08	55^{+17}_{-13}
	1975.8 ± 0.6	0.84 ± 0.15	
	2925 ± 1	0.61 ± 0.09	
6379.3 ± 0.4	1498.8 ± 0.4	0.98 ± 0.15	< 27
	2232.3 ± 0.7	0.85 ± 0.13	
	3181 ± 1	0.90 ± 0.11	
6480.9 ± 0.5	2309.1 ± 0.4	0.91 ± 0.07	< 24
6520.3 ± 0.5	2348.5 ± 0.7	0.92 ± 0.13	11^{+5}_{-4}
	2373.3 ± 0.6	0.97 ± 0.12	
	3845.5 ± 1.0	0.92 ± 0.03	
	3845.5(SE)†	0.87 ± 0.10	
	3845.5(DE)†	0.96 ± 0.07	
6710.0 ± 0.4	1524.2 ± 0.2	0.83 ± 0.07	16^{+6}_{-6}
	2300.0 ± 0.4	0.98 ± 0.08	
	2538.5 ± 0.4	0.88 ± 0.05	

† SE, single escape peak; DE, double escape peak.

(1) I.P.JOHNSTONE, Phys.Rev. C17 1428 (1978)

COULOMB EFFECTS IN α-INDUCED DEUTERON BREAKUP

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The $^{2}H(\alpha,\alpha p)n$ reaction has been widely investigated in the past, mainly to get information on the potentials between clusters (α,p,n), comparing experimental data with theoretical predictions based on the numerical solution of Faddeev equations.

This approach implies a three-body model in which the alpha particle is assumed as structureless and its internal degrees of freedom are taken into account to some extent only via the effective alpha-nucleon interaction. In most cases the theoretical calculations reproduce rather well the experimental data. Nevertheless there are regions, especially in the breakup channel, where the theoretical predictions differ considerably from experimental data. The discrepancy between theory and experiment becomes more pronunced at lower energies ($E_{\alpha}^{Lab} \lesssim$ 12 MeV).

The reason of the discrepancy can be attributed to the inadequate treatment of Coulomb force.

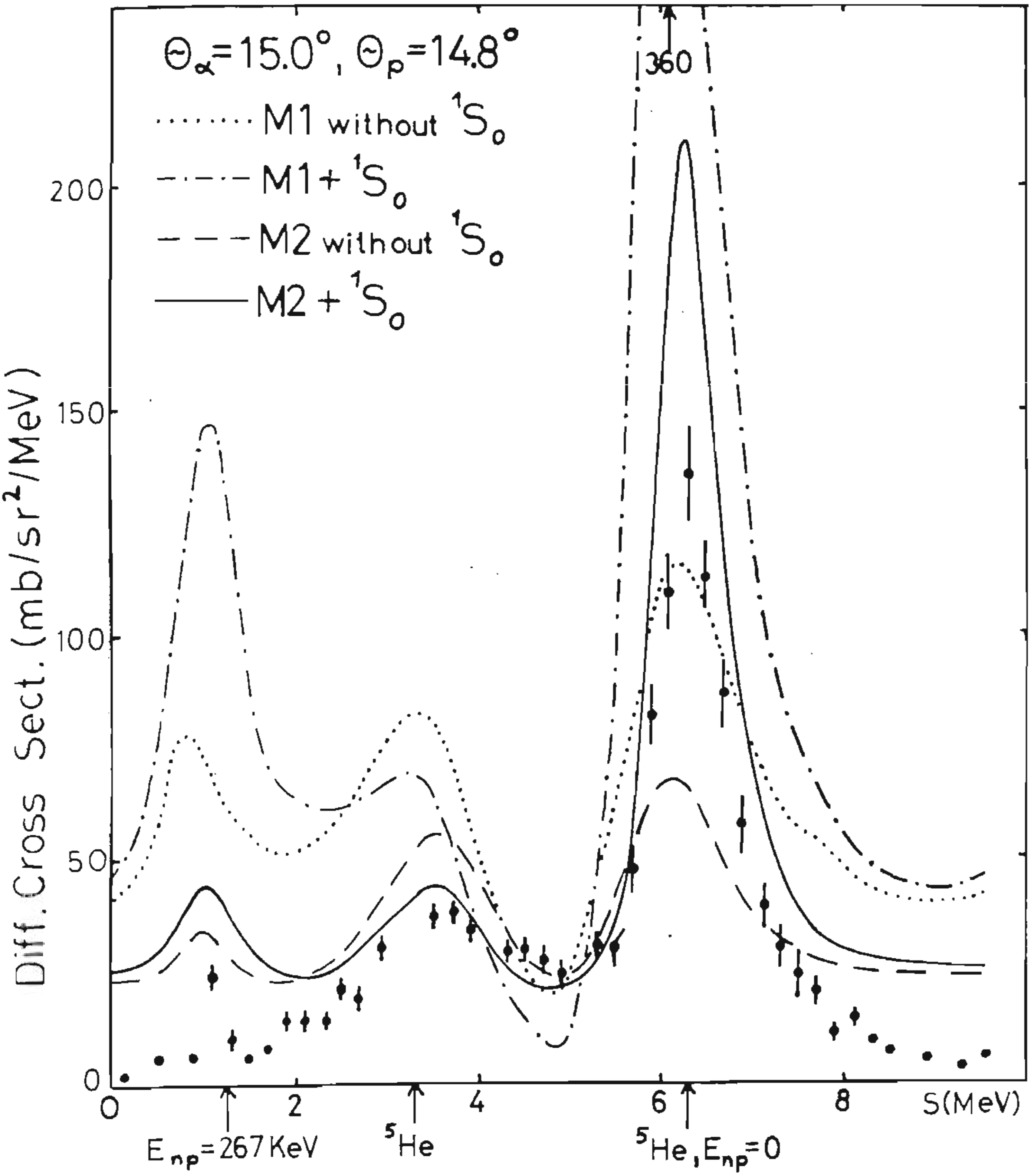
An investigation of the breakup reaction $^{2}H(\alpha,\alpha p)n$ at 11.3 MeV has been performed with the aim of getting more information on Coulomb effects at energies quite close to threshold.

The experimental differential cross sections were compared with new theoretical calculations, where the Coulomb effects are taken into account in the interaction matrix, as well as in the ingoing and outgoing channels. First, pure Coulomb contributions are taken into account in the alpha-proton subsystem only using Coulomb distorted separable potential form factors. As a second step the Coulomb interaction is taken into account as an intermediate range Coulomb repulsion in the p-alpha two-body subsystem.

The results of the calculations of these two models, compared with experimental data, are plotted in Fig. No. 1.

Even if this approach is still a very simple approach to the Coulomb problem, a better agreement with experiment has been achieved.

Further developments of this model are in progress as well as the possibility of treating in a correct way the Coulomb interaction in a coordinate space Faddeev type calculations.


Θα=15.0°, Θp=14.8°
M1 without ¹S₀
M1+¹S₀
M2 without ¹S₀
M2+¹S₀
360
Diff. Cross Sect. (mb/sr²/MeV)
0
50
100
150
200
0
2
4
6
8
S(MeV)
Enp=267 KeV
⁵He
⁵He, Enp=0

ELASTIC ENHANCEMENT FACTOR IN $^{29}Si(p,n)$ CHARGE EXCHANGE REACTIONS.

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Charge exchange reactions like (p,n) can be viewed as a form of elastic scattering if isospin is conserved. Compound elastic scattering is enhanced over inelastic channels due to the self-correlation of the elastic scattering S-matrix elements. If the matrix elements, coupling the compound states to the open channels, have a Gaussian distribution, statistical theories of compound nucleus reactions[1] predict the enhancement factor, called Width Fluctuation Correction(W.F.C.), to be equal to 2 in the limit of a very large number of open channels. One may expect charge exchange reactions to behave similarly as long as entrance and exit channels are correlated through isospin conservation[2].

In orderto experimentally deduce the W.F.C. factor and to test the theory, we chose, as suggested[3], to study the $^{29}Si(p,n)$ reaction at incident energy between 14-20 MeV, which allows to excite the compound nucleus at 20-25 MeV.

By using the pulsed beam facility of the Tandem laboratory, the neutrons will be detected by means of the time of fligth method. The mechanical apparatus, the shielding systems and the electronic set-up, have been tested by us last year. The overall time resolution is about 1.5 nanoseconds, which allows to resolve the neutrons of our interest with a flight path of about 2÷3 meters.

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1) C.Mahaux and M.A.Weidenmüller, Ann.Rev.Nucl.,Part.Sci.29,(1979),1

2) H.A. Weindenmüller et al., Phys.Rev. C18,(1978),1953

3) H.L.Harney et al., Phys.Rev. C16,(1977),1774 .

ENERGY BEHAVIOUR OF THE QUASI-FREE PROCESS $^{9}Be(^{3}He,\alpha\alpha)^{4}He$

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The $^{9}Be(^{3}He,\alpha\alpha)^{4}He$ reaction has been studied at low incident energies by many authors. In addition to the sequential reaction mechanisms proceeding through ^{8}Be levels, a quasi-free contribution has been observed to proceed through the virtual reaction $^{5}He + ^{3}He \rightarrow \alpha + \alpha$. This latter process has been already studied at 4 MeV (1) and between 1 and 3 MeV(2). The Treiman-Yang criterion was also applied to test the polar nature of the reaction (3). In order to have a better understanding of the importance of this process at low energies, its energy behaviour was followed from 3 to 12 MeV.

The experiment was performed by using a ^{3}He beam from the CN VdG accelerator at LNL and ^{9}Be targets evaporated on C backings. For each run outgoing particles were detected at symmetrical angles (quasi-free angular configuration); bidimensional spectra were also collected at asymmetrical angles where the quasi-free process is expected not to contribute to the reaction cross section. The measurements were performed at 3, 3.5, 4, 4.5, 5, 6, 9, 12 MeV. The events were analyzed by projection both on one of the energy axes and on the energy difference coordinate.

The excitation function of the quasi-free peak, obtained between 1 and 12 MeV by taking into account also data from our previous experiment, shows a broad resonance around 3 MeV. The interpretation of this structure is in progress.

References

(1) J.Kasagi et al., Nucl.Phys. A239(1975)233 and references therein.
(2) N.Arena et al., Nuovo Cimento A45(1978)405.
(3) P.G.Fallica et al., Phys.Rev. C24(1981)1394.

QUASI-FREE PROCESSES IN THE INTERACTION OF ^3He WITH Li ISOTOPES

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Two different experiments have been performed to study quasi-free processes in the interaction of low energy ^3He ions with Li isotopes.

In the first experiment the $^6Li(^3He,p\alpha)^4He$ reaction was chosen to test the use of the two-body scattering cross-section, taken on the energy shell, in the analysis of these processes using the impulse approximation. Two previous experiments, using the $^6Li(\alpha,2\alpha)$ reaction and well known resonances in α-α scattering gave different results. In the first case (1) it was shown that the two-body cross-section should be used in the "prior" form, while in the second case (2) satisfactory agreement was obtained when only a potential scattering contribution to the free scattering cross-section was used. In our experiment the resonance in the $^2H(^3He,p)^4He$ reaction corresponding to the 16.66 MeV state in ^5Li was used. The $^6Li(^3He,p\alpha)^4He$ reaction was studied by using ^3He beam at the CN VdG (LNL). The angular correlation between α and p was measured at 3 different energies around the expected resonance. The obtained results seem to be in agreement with the findings of Ref(2).

A second experiment was performed to study the quasi-free process $^7Li(^3He,\alpha\alpha)d$ in which the deuteron is spectator (in the beam) of the virtual reaction $^7Li(p,\alpha)\alpha$. Coincidence detection of the two α-particles gave evidence for such a process at E = 10 and 12 MeV. Further work is planned to measure the cross-section of the process at different energies and/or angles.

References

(1) P. Gaillard et al., Phys. Rev. Lett. 25 (1970), 593
(2) D. Gola et al., Phys. Rev. C27 (1983), 1394

SEARCH FOR RESONANCES IN THE $^{24}Mg(^{32}S,\,^{32}S)^{24}Mg$ REACTION

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One of the most intriguing problems in the research field concerning the study of resonances induced in heavy ion reactions is the correspondence (or not) in a compound nucleus of the energy, spin and parity of quasi-molecular states when the compound nucleus is obtained via different entry channels. The advent of large Tandem accelerators allows the extension to a lot of systems of this kind of investigation, whereas in the past the ^{30}Si nucleus (obtained by means of the $^{12}C+^{18}O$ and $^{14}C+^{16}O$ reactions ([1])) has been the only nuclear system extensively studied, and there are only a few results concerning the ^{44}Ti system (obtained by means of the $^{28}Si+^{16}O$ and $^{32}S+^{12}C$ reactions ([2])).

The ^{56}Ni nucleus, that has been recently got by means of the $^{28}Si+^{28}Si$ reaction ([3]) is one of the most interesting systems in this field, both because it is at present the heaviest one where well shaped resonances have been observed, and because these resonances have the highest L-values (L=34, 36, 38, 40, 42) observed up to new. For these reasons, we decided to study this nucleus through the measurement of the excitation function of the elastic scattering of ^{32}S ions from a ^{24}Mg target. The measurements were made in a scattering chamber by using the kinematical coincidence method with three Si detectors. A first detector was placed at a forward angle of -20° to measure the elastically scattered ^{32}S ions, a second one was placed at the corresponding backward angle of 67.5° to measure the recoil ^{24}Mg ions. A third detector was finally placed at an angle of 20° (symmetric to the first-detector angle) in order to monitor the beam position on the target. The target was a 50 $\mu g/cm^2$ evaporation of enriched $^{24}MgO_2$ on a 100 $\mu g/cm^2$ Au backing.

The energy region where the presence of the resonances may occur in the $^{32}S+^{24}Mg$ channel (calculated from the experimental results taken from the $^{28}Si+^{28}Si$ measurements) was then investigated in steps of 1 MeV or 0.5 MeV, repeating some measurements in order to be sure of the reproducibility of the data. The results are reported in fig. 1 as cross sections in arbitrary units versus the ^{32}S incident ions energy. No evidence was found of the presence of structures exceeding the usual values of the statistical fluctuations, but a possible statement on the presence or absence of resonances requires some complementary measurements at other couples of angles.

(1) G. Vourvopoulos, X. Aslanglou, C.A. Kalfas, N. Cindro, E. Holub, D.M. Drake, J.D. Moses, J.C. Peng, N. Stein and J.W. Sunier
In "Resonant Behavior of Heavy-Ion Systems", ed. by G. Vourvopoulos, National Printing Office, Athens 1981, pp. 449.

(2) N. Cindro
Rivista del Nuovo Cimento 4, n. 6 (1981) 1.

(3) R.R. Betts, S.B. Di Cenzo, J.F. Petersen
Phys. Lett. 100B (1981) 117.

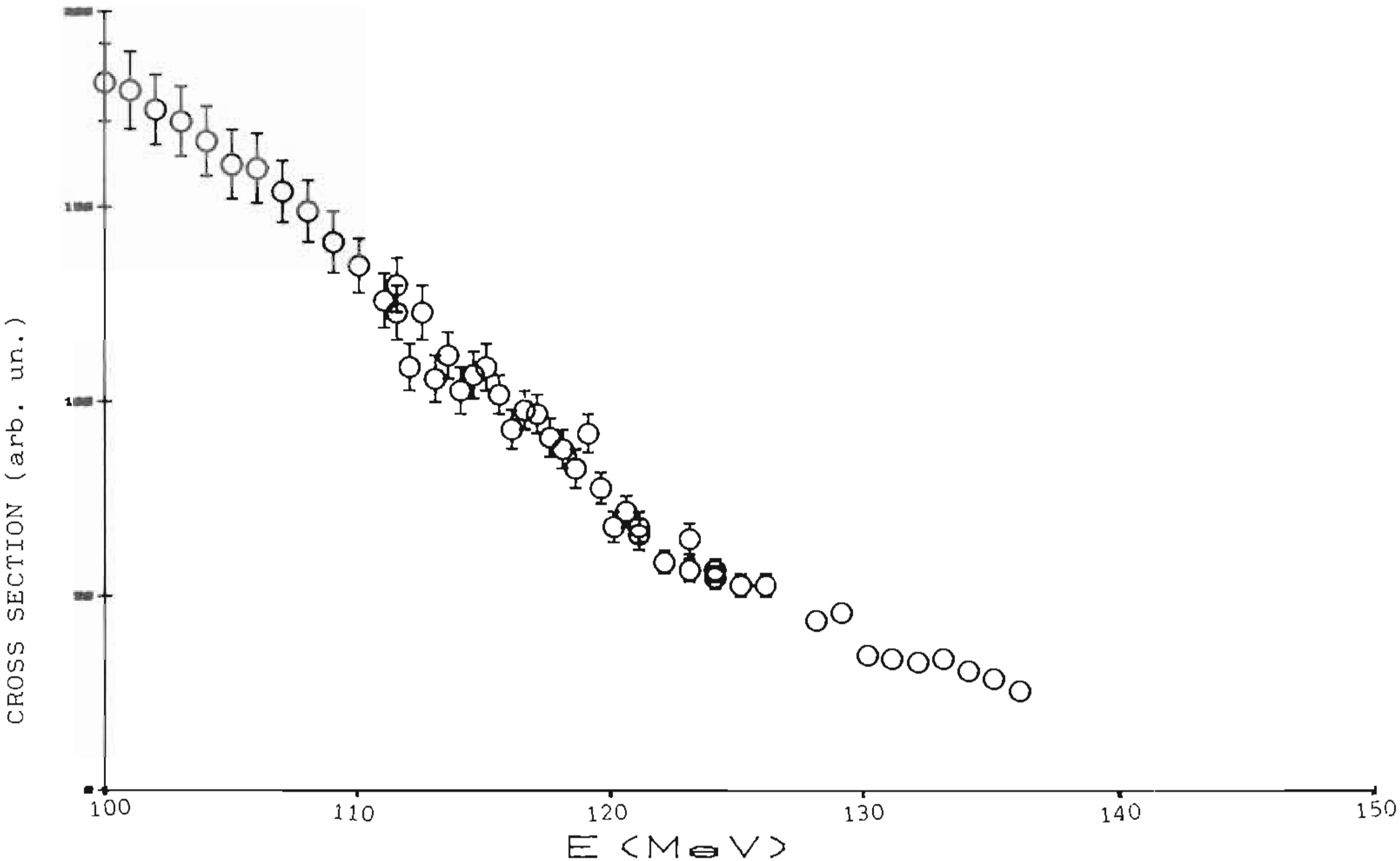

Fig. 1 - Excitation function of the $^{24}Mg(^{32}S, ^{32}S)^{24}Mg$ reaction for incident ^{32}S energies from 100 to 136 MeV.

CHARACTERISTICS OF THE FISSION-LIKE FRAGMENTATION OF MEDIUM MASS NUCLEAR SYSTEMS ($E/A \leq 10$ MeV/u)

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The study of the fission-like fragmentation of medium mass composite systems formed in heavy ion collisions has evidenced the following characteristics[1-5]:

i) the fragment mean kinetic energies are fully relaxed, in agreement with Viola's systematics for fission processes;

ii) the fragment mass distributions exhibit a pronounced dependence on the composite system mass, the entrance-channel mass asymmetry, the bombarding energy and the observation angle;

iii) the fragment angular distributions are compatible with $1/\sin\theta_{CM}$ behaviour only for some systems, while generally an evolution is observed as the fragment mass approaches the projectile (and target) mass.

In this mass region, the relaxation of the mass asymmetry degree of freedom, normally observed in fusion-fission but not in fast deep-inelastic processes, has been experimentally evidenced in the study of the $^{32}S+^{59}Co$[3,5] and $^{32}S+^{63}Cu$[6] reactions. The mass distributions of the fission-like fragments from the last reaction are presented in fig. 1 for the bombarding energies E_{LAB}=140, 154 and 168 MeV. As previously found in the case of the $^{32}S+^{59}Co$ reaction (studied both with the Strasbourg and the Legnaro Tandem accelerators), in the present reaction memory of the entrance channel mass asymmetry is evidenced by pronounced peaks around the target (and projectile) mass.

However, for the highest bombarding energies investigated, the mass spectra evolve toward more symmetrical shapes (peaking around half the composite system mass, $A_{CS}/2$) with decreasing the observation angle. The fragment mean kinetic energies, characteristic of a fully damped process, can be reproduced by the sum of the Coulomb and rotational energies corresponding to each exit channel mass division. This indicates that the system configuration at scission corresponds to a very deformed and rapidly rotating dinucleus. Moreover, the observed angular dependence of the mass distributions suggests that for these systems the relaxation of the mass asymmetry proceeds in a time scale comparable with the rotation period of the composite system ($\sim 10^{-21}$S). This reaction mechanism, intermediate between fusion-fission and deep-inelastic processes, has been inter-

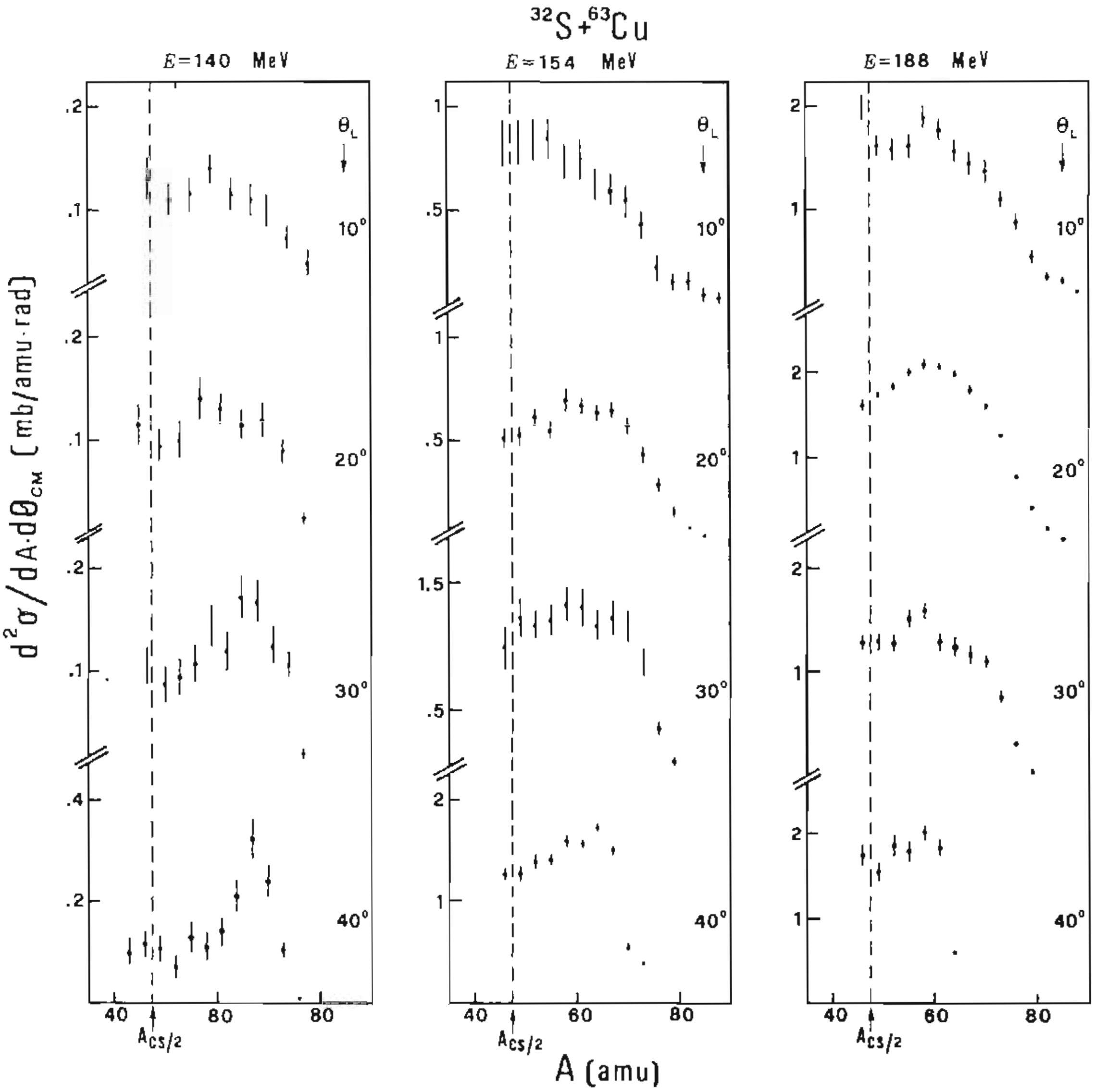

Fig. 1. - Center-of-mass double differential cross sections of the fission-like events as a function of fragment mass for the $^{32}S+^{63}Cu$ reaction.

preted in terms of a continuous relaxation process, leading the system from the entrance channel to more or less equilibrated configurations, depending on the system lifetime[7]. In this framework, calculations based on a recent formulation of the transport theory - assuming statistical nucleon exchange between the interacting nuclei to be the dominant dissipative mode - could reproduce the experimental distributions observed in quite different situations:

i) mass spectra evolving with bombarding energy and/or observation angle ($^{32}S+^{59}Co$, $^{32}S+^{63}Cu$);

ii) symmetrical mass spectra, peaking around $A_{CS}/2$, showing no evolution with the bombarding energy nor with the observation angle ($^{32}S+^{76}Ge$[2]), as would be from a fusion-fission process;

iii) element distributions showing complete separation between projectile-like and symmetric (around $Z_{CS}/2$) components ($^{12}C+^{89}Y$[8])), as would result from the contribution of both deep-inelastic and fusion-fission processes.

The mean lifetimes extracted through fits to the experimental data are $\sim 10^{-21}$ S for the first two classes of reactions, whereas a value $\sim 10^{-22}$ S results from the analysis of the $^{12}C+^{89}Y$ reaction; this still supports the idea of a relaxation process of the system degrees of freedom which is limited by the available interaction time[9]). This picture, which seems to apply quite generally to the phenomenology of fission-like reactions in the medium mass region, can be schematically represented as in fig. 2.

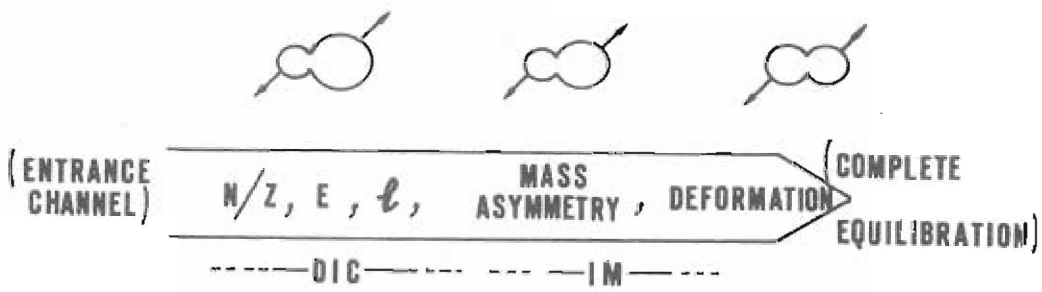

Fig. 2. - Schematic path of reaction flow in a dissipative collision. Neutron-to-proton ratio (N/Z), energy (E), angular momentum (ℓ), mass asymmetry and deformations are progressively equilibrated according to increasing characteristic times.

References

(1) H. Oeschler et al., Phys. Lett. 87B (1979) 193.

(2) G. Guillaume et al., Phys. Rev. C26 (1982) 2458.

(3) J.P. Coffin et al., Phys. Rev. C30 (1984) 539.

(4) M. Gentili et al., Lettere al Nuovo Cimento 36 (1983) 97.

(5) I. Iori et al., Phys. Lett. 132B (1983) 304.

(6) P. Boccaccio et al., Contrib. to the Second Int. Conf. on Nucleus-Nucleus Collisions, Visby, 1985.

(7) M. Gentili et al., Lettere al Nuovo Cimento 40 (1984) 505.

(8) J.B. Natowitz et al., Ohys. Rev. C13 (19876) 171.

(9) P. Boccaccio and R.A. Ricci, Proc. 5th Adriatic Int. Conf. on Nuclear Physics, HVAR, 1984.

LIMITATION TO COMPLETE FUSION IN THE REACTION ^{30}SI + ^{30}SI

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The fusion excitation function for the reaction ^{30}Si + ^{30}Si has been measured at L.N.L. by in-beam γ-ray spectroscopy at incident energies in the range 90-120 MeV. The results together with those at lower energies (ref.1) are reported in fig.1 as total fusion cross section versus $1/E_{CM}$ showing at high energy a deviation from the expected linear behaviour.

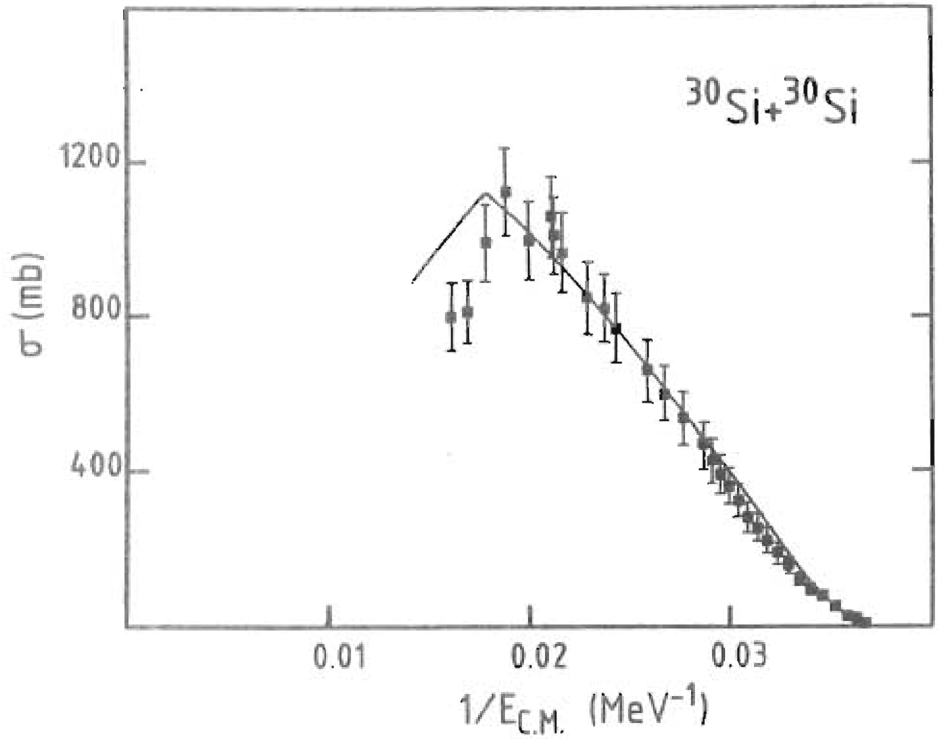

Fig. 1 Fusion excitation function for the reaction ^{30}Si + ^{30}Si. The full line is the result of a barrier penetration calculation performed using the K.N.S. potential.

In order to understand the kind of limitation to the complete fusion, a comparison with the data previously measured for the system $^{12}C + {}^{48}Ti$ [1] leading to the same compound nucleus is presented in fig.2 as excitation energies versus J(J+1). A limitation to complete fusion due to the yrast line of the compound nucleus would appear in this representation as an overlapping of the two experimental results starting from a certain angular momentum value. It can clearly be seen that this is not the case. The statistical yrast line calculated assuming a rigid moment of inertia for the compound nucleus and using the empirical scaling factors suggested by Lee [2] is also reported.

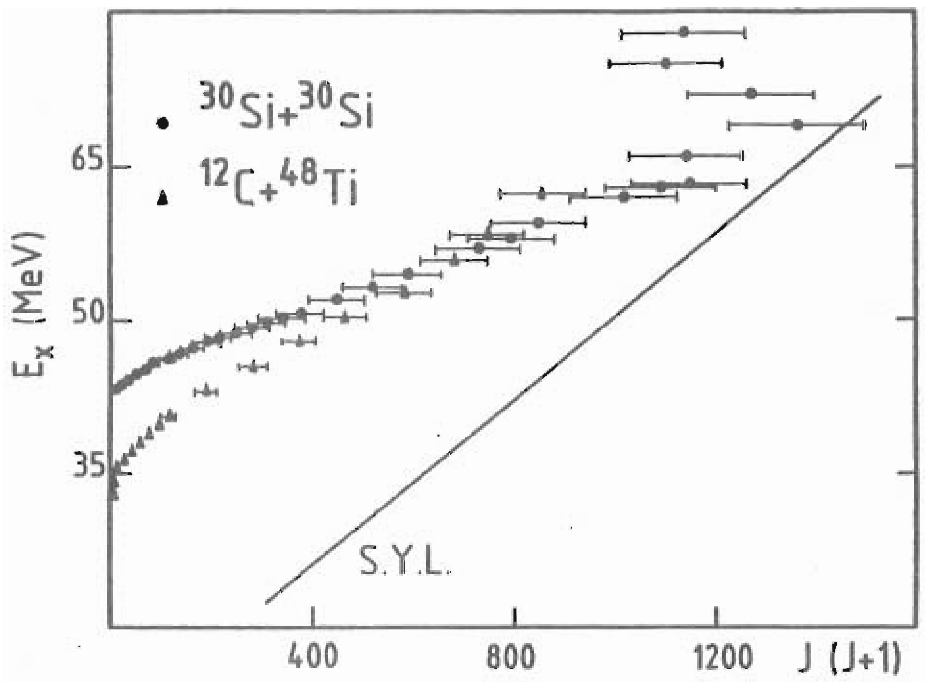

Fig. 2 Fusion excitation functions for the reactions $^{12}C + {}^{48}Ti$ (triangles) and $^{30}Si + {}^{30}Si$ (dots) plotted as compound nucleus excitation energy vs. angular momentum. The full line (S.Y.L.) represents the statistical yrast line.

An approach based on a limitation related to the entrance channel properties has then been followed. In the framework of an unidimensional barrier penetration model we have calculated the excitation function for the $^{30}Si + {}^{30}Si$ system taking the Krappe, Nix and Sierk [3] potential for the nucleus-nucleus interaction. The results of this calculation are shown as full line in fig.1. It appears that barrier height and position are fairly well reproduced as well as the critical energy [4].

The possible limitation due to the statistical yrast line and the nature of the process competing with the complete fusion are at the present under investigation. To this end, charged particles and light-heavy ions angular distributions have been measured in the angular range 20° - 160° at incident energies of 100 and 120 MeV, which lie below and above the critical energy, respectively. Data analysis is in progress.

REFERENCES

1) D.M. De Castro Rizzo, E. Bozek, S. Cavallaro, B. Delaunay, J. Delaunay, H. Dumont, M.G. Saint Laurent and F. Terrasi. Nucl. Phys. A427 (1984) 151.

2) S.M. Lee, Proc. of the Tsukuba Symp. on heavy ion nuclear physics, Tsukuba (1981).

3) H.J. Krappe, J.R. Nix and A.J. Sierk, Phys Rev. C20 (1979) 992.

4) H. Dumont, B. Delaunay, J. Delaunay, D.M. Rizzo, A. Brondi, P. Cuzzocrea, A. D'Onofrio, R. Moro, M. Romano and F. Terrasi. Nucl. Phys. A435 (1985) 301.

STUDY OF FUSION REACTION BETWEEN ^{32}S AND $^{24,25,26}Mg$ IN ENERGY REGION E_{lab}=90-150 MeV

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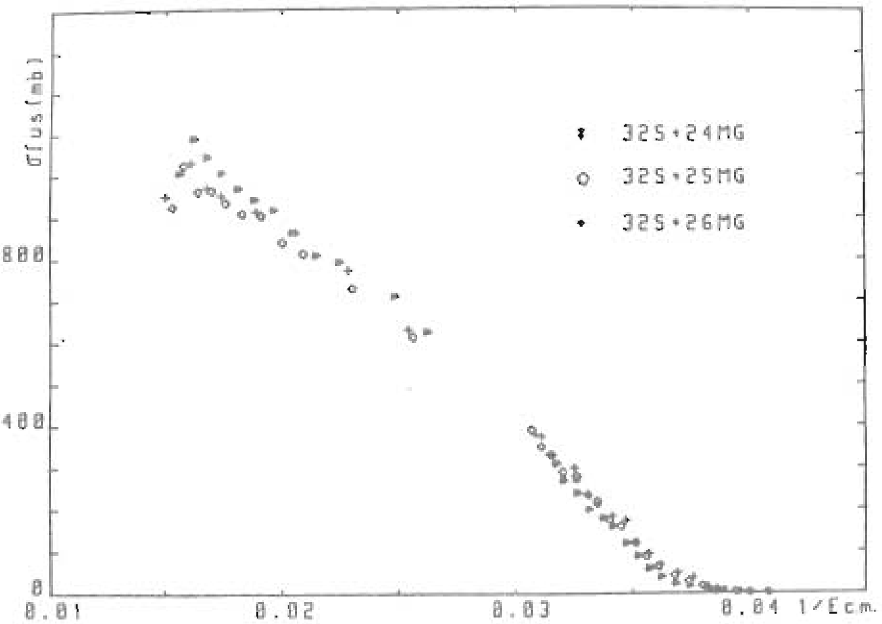
The fusion excitation functions of $^{32}S+^{24,25,26}Mg$ in incident energy region E_{lab}=90 MeV to 150 MeV were measured by means of in beam γ-spectroscopy method. In order to suppress background and take into account the contribution of unstable residual nuclei to the in-beam yields of the "daughter" residual ones, a computer-controlled chopper-system was assembled on the beam line to measure the in-beam and off-beam spectra of the γ-rays.

Special efforts were made to carry out the accurate measurements of the target thickness, including the estimation of the contamination of ^{16}O and ^{12}C. Detailed comparison was made between the present measurement and the available data obtained by other methods. The measured A and Z distribution was compared with statistical calculations. The fusion excitation functions, which exhibite an obvious bending showing strong limitation on the fusion in this energy region, was fitted by the new critical distance model and the extra-push one. Extra-push results suggest that a quasi-fission process can be present for E_{lab}≃150 MeV.



Experimental fusion cross section v/s $1/E_{cm}$.
Low energy data are from

G.M.Berkowitz, P.Braun-Munzinger, J.P.Karp, R.H.Freidelder, T.R.Renner and H.W.Wilschut, Phys.Rev. C28(1983)667.

PREEQUILIBRIUM EMISSION IN THE $^{12}C(^{16}O,\alpha)$ REACTION

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The excitation functions relative to the low lying states populated by the $^{12}C(^{16}O,\alpha)$reaction have been measured in the energy range 24.0 ÷ 43.2 MeV laboratory, in 200 keV steps, at θ_{lab}= 20° and 135° (these angles are symmetric in the center of mass). The measurements have been taken making use of Si detectors in the +20° scattering chamber of the L.N.L. XTU tandem accelerator laboratory.

The presence of multistep compound statistical fluctuations in the excitation functions has been confirmed. These had already been evidentiated in light (1) and heavy (2) ion induced reactions and preliminarily studied by analysing excitation functions present in the literature (3).

The use of the spectral density method (SDM) has allowed the extraction of the corresponding coherence energies. Values in the range 150 ÷ 350 keV have been obtained.

Further analyses are in progress to investigate a possible incident energy dependence of these widths, thus providing useful information to understand fusion processes and about the possible molecular nature of the doorway states which give rise to such statistical fluctuations.

References

(1) R. Bonetti et al.; Phys. Rev. C28 (1983) 1892

(2) A. De Rosa et al.; Nuovo Cimento, in press

(3) A. De Rosa et al.; Phys. Rev. C27 (1983) 2688

PROJECTILE- AND TARGET-LIKE FRAGMENT EXCITATION IN THE $^{32}S+^{58}Ni$ REACTION AT 143 MEV

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The division of the excitation energy between the two fragments, is one of the open questions in Heavy-Ion collisions at energies below 10 MeV/A.

Experiments on neutron emission seem to indicate that the system is thermalized not only when the available kinetic energy is dissipated but also for incompletely relaxed events[1].

However recent experiments[2,3] and new analysis of neutron data[2] support the hypothesis of an equal excitation energy in the fragments at small energy loss, followed by a transition to the thermal equilibrium regime at large energy loss, as expected from transport theory calculations[4].

We report on an experimental investigation of projectile--like (PLF) and target-like (TLF) fragment excitation in the $^{32}S+^{58}Ni$ reaction at 143 MeV by means of the discrete γ-ray line spectroscopy in coincidence with identified PLF (E,Z).

The experiment was performed at the XTU Tandem facility of the L.N.L. The PLF were detected at θ=30° by the Position-Sensitive Bragg Curve Ionization Chamber[5]. A Ge detector (30% efficiency) was at θ=90° in the reaction plane and a second Ge (20% efficiency) was positioned normal to the reaction plane. Coincidences between the Ge and the H-I detectors were recorded: an event was defined by energy, Bragg Peak amplitude and position of PLF, E_γ and coincidence time. Inclusive spectra were also recorded.

E_γ-Q matrices were analyzed for the more abundant PLF atomic numbers ($Z_{p\ell f}$=16,15,14) and for the two Ge detectors. Data for $Z_{p\ell f}$=16,14 are here reported.

The following results have been obtained:

1) for the outgoing channel $^{28}Si+^{62}Zn$, the relative decay probability of the excited ^{62}Zn primary fragment via γ, pγ and αγ was obtained as a function of the two-body kinematics Q-value, as shown in fig. 1.

2) For the $^{28}Si+^{62}Zn$ channel the absolute PLF excitation probability was calculated by normalizing the ^{28}Si γ-yield to the Z_{plf}=14 single spectrum, corrected for the $^{28}Si/Si$ isotopic ratio[6].

3) The ratio of the γ-yields from projectile and target was obtained for the outgoing channels $^{28}Si+^{62}Zn$ and $^{32}S+^{58}Ni$ (fig. 2).

In the $^{32}S+^{58}Ni$ channel the γ-decay probability for projectile and target is nearly the same, while in the $^{28}Si+^{62}Zn$ channel ^{28}Si yields less γ-rays than ^{62}Zn at the same Q: that may be attributed to strong structure effects.

For a thermally equilibrated system[7], the probability distribution for the division of the totale excitation energy is assumed to be proportional to the product of the level density of the two fragments. The data have been compared with calculations based on such assumption, taking into account the levels in the γ-ray energy range detected.

The comparison is shown in fig. 2: the calculation is well below the experimental points at Q>-20 MeV and reproduces the data only around the barrier (Q∿-32 MeV). It seems that the thermal equilibrium is established only when all the kinetic energy has been dissipated.

In the quasi-elastic region the experimental data suggest that the light fragment has more excitation energy than at the equilibrium. The equipartition limit is checked for Q>-20 MeV by comparing the decay probability of the TLF ^{62}Zn with the CASCADE code[8] evaporation calculations.

At $E_x=Q/2$ and assuming a linear fragment spin scale ($S=0\hbar$ at Q=0 and S equal to the sticking limit at the barrier), the calculations indicate for $^{62}Zn^*$ mostly γ deexcitation, while p and α decay is experimentally observed (fig. 1).

At small Q-values, for the present data, the division of the excitation energy is between the equipartition and thermal equilibrium limits.

Structure effects in the projectile excitation found for the two outgoing channels ($^{32}S+^{58}Ni$ and $^{28}Si+^{62}Zn$) are observed in a recent investigation on the energy partition in quasi-elastic Kr induced reactions[9].

References

(1) L.G. Moretto, Proc. Int. Conf. on Nucl. Phys., Florence 1983, p. 385 and references cited therein.

(2) T.C. Awes et al., Phys. Rev. Lett. 52 (1984) 251.

(3) R. Vandenbosch et al., Phys. Rev. Lett. 52 (1984) 1964.

(4) J. Randrup, Nucl. Phys. A383 (1982) 468.

(5) A. Moroni et al., Nucl. Instr. and Meth. 225 (1984) 57.

(6) W. Dunnweber, Proc. E. Fermi School, Varenna 1983, p. 389.

(7) D.J. Morrissey et al., Phys. Rev. C23 (1981) 1835.

(8) F. Pulhofer, Nucl. Phys. A364 (1981) 125.

(9) H. Solbach et al., Proc. Workshop on Nucl. Dynamics III, Colorado 1984, p. 72.

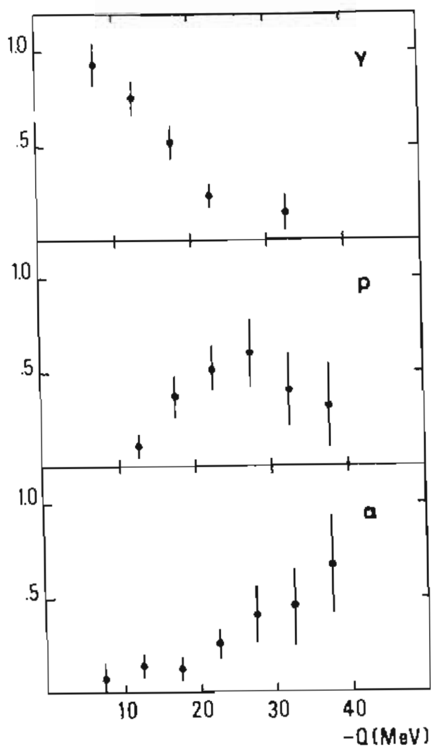

Fig. 1. - Decay probability of the primary $^{62}Zn^*$ fragment via γ, p, α.

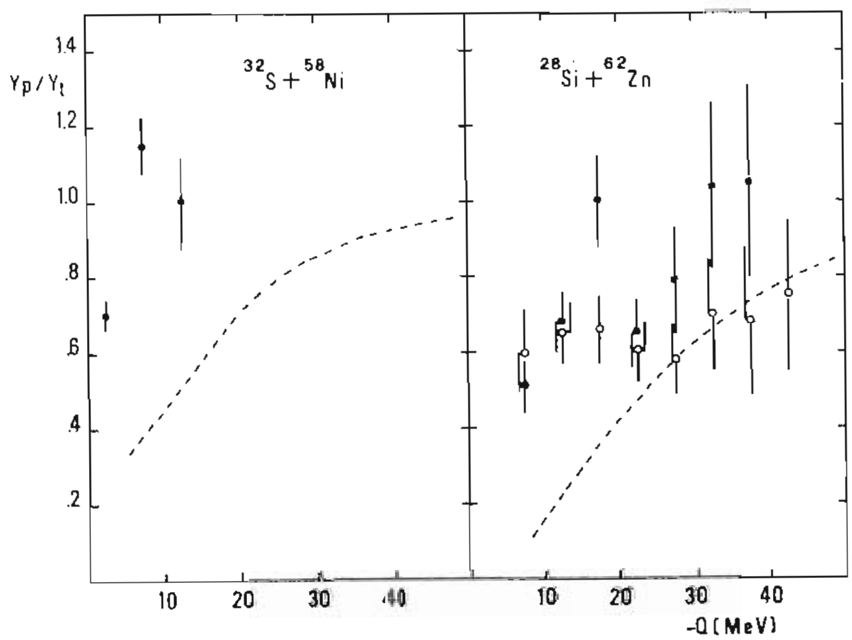

Fig. 2. - Ratio of the γ-yields from projectile and target for the outgoing channels $^{32}S+^{58}Ni$ and $^{28}Si+^{62}Zn$ and absolute ^{28}Si projectiles excitation probability (open dots).

SEARCH FOR LARGE ANGULAR MOMENTUM INDUCED DEFORMATIONS OF ^{67}Ga

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A multi-detector experiment has been performed in August 1984 at the Variable Energy Cyclotron of the Texas A&M University (College Station). The aim of the experiment was to study the deformation of compound nuclei produced at high angular momentum in heavy-ion collisions. As shown for the reaction ^{32}S+^{27}Al, the nuclear deformation strongly influences the spectra of the emitted light particles and these effects can be accounted by detailed statistical model calculation[1].

In the present experiment the studied compound nucleus was ^{67}Ga produced, at the same excitation energy but with a different spin distribution, by the reactions

^{40}Ar+^{27}Al	at 240 MeV
^{16}O+^{51}V	at 115 MeV
^{12}C+^{55}Mn	at 130 MeV
^{4}He+^{63}Cu	at 120 MeV

The experimental set-up consisted in two triple telescopes of Solid State detectors (15-300-5000 μm and 15-250-5000 μm) for the light particles (LP) detection and two gas detector systems with large solid angle to detect the HI: the BBC spectrometer[2] and the Large Ionization Chamber (LIC)[3]. The BBC spectrometer was placed at θ=-20° subtending an angle $\Delta\theta$=±5°, the LIC was at θ=+20° with an acceptance angle $\Delta\theta$=±10°. For the reaction studied we collect detailed inclusive angular distributions for the light particles and coincidences between LP telescopes and evaporation residues detected in the LIC.

Furthermore for the Ar+Al system we also collect the coincidences between the LP telescopes and the two heavy ion spectrometers fragment-fragment and fragment-fragment-light particles to study the decay of the composite system. The fragment-fragment angular correlation was studied for different angular setting of the LIC (θ=20°, 40°, 60°; $\Delta\theta$=20°).

Absolute normalization of the cross sections was obtained in a separate elastic scattering experiment. The data analysis is in progress.

References

(1) R.K. Choudhury et al., Phys. Lett. 143B (1984) 74.

(2) A. Moroni et al., Nucl. Instr. and Meth. 225 (1984) 57.

(3) H. Sann et al., Nucl. Instr. and Meth. 124 (1975) 509.

SUB-BARRIER FUSION OF THE SYSTEMS $^{28,30}Si+^{58,62,64}Ni$

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Heavy-ion fusion at energies below the Coulomb barrier, as evidenced by recent experiments[1,2,3], is a process by far more likely than how models based on one-dimensional barrier penetration[4] predict, also when considering empirical barrier heights and positions[5].

A research program is in progress at the XTU Tandem accelerator, aiming at a detailed understanding of the mechanism leading to fusion in medium-light systems.

The systems investigated[6] are $^{28,30}Si$ (beams) on $^{58,62,64}Ni$ (targets) at energies ranging from 0.9 to 1.2 times the Coulomb barrier. The Nickel targets were rolled, self-supporting foils ($\sim$250 μg/cm ^{2}) enriched to 99.8, 97.8, 96.5% in mass 58, 62 and 64 respectively. The reaction $^{28}Si+^{58}Ni$ was also reversed (^{58}Ni beam), to have a check of the absolute cross-section scale.

Differential cross-sections at 0° were measured using an electrostatic deflector[7] to separate the transmitted beam from the evaporation residues (ER), and a time-of-flight energy telescope[8] with micro-channel-plates and a solid state detector was placed after the deflector.

The beam rejection factor was typically 10^8 and the ER's were clearly resolved from the residual beam like particles (fig. 1). A sensitivity to cross-sections as small as 1 mb/sr was thus achieved.

The whole set-up was rotated to measure the ER angular distributions for all the systems at representative energies. Some examples of angular distributions are shown in fig. 2.

Total fusion cross-sections were obtained by integration of the smoothed ER angular distributions, assuming shapes slowly varying with the incident energy. Estimated errors are 20% in the absolute cross-section scale (30% at the lowest measured energies). The largest uncertainties come from the angular distribution integrations and from the ion transmission through the deflector.

In fig. 3 the measured fusion-evaporation cross-sections are plotted vs. the centre-of-mass energy. Corrections for the beam energy losses in the targets were done and the overall accuracy of the energy scale is ±100 keV.

Fig. 4 shows a plot of reduced cross sections vs. the energy distance from the classical Coulomb barrier. The choice of other barriers (e.g. ref. 5) does not change the picture qualitatively.

The cross sections are reduced from the experimental ones, choosing the system $^{28}Si+^{64}Ni$ as a reference by correcting for the nuclear radius differences.

The amount of sub-barrier cross-sections for all these relatively light systems ($Z_1{*}Z_2 \cong 400$) is large and this is expected, since it was observed[9] in still lighter projectile-target combinations. For the reference systems $^{28}Si+^{64}Ni$ there is still ~1 mb of fusion cross-section 7 MeV below the barrier, two-three orders of magnitude more than the predictions of one-dimensional barrier penetration calculations.

We note also that the sub-barrier points for the three ^{28}Si-induced reactions are spread over more than one order of magnitude below the 10 mb level, the ^{64}Ni target being most favoured. This is difficult to interprete, in terms only of zero--point motion[10] and/or coupling to inelastic channels, because no difference exists, within the experimental errors, between e.g. the $^{30}Si+^{62,64}Ni$ excitation functions.

We are then naturally led to take into account the coupling to other modes, such as the two-neutron transfer, which has positive effective[11] ground state Q-values only in the cases of $^{28}Si+^{64,62}Ni$ (+2.8 MeV and +0.9 MeV, respectively).

Considering however the ^{30}Si-induced reactions, we note that the cross-sections for the three systems are very close to each other. Here the effective Q-values for one- and two-nucleon transfer are all negative, except for the $^{58}Ni(^{30}Si,^{28}Si)^{60}Ni$ reaction, whose Q-value (+1.1 MeV) would lead to the simple prediction of an enhancement similar at least to what observed for $^{28}Si+^{62}Ni$. But the $^{30}Si+^{58}Ni$ fusion cross-sections is not enhanced.

A quantitative comprehension of the present results needs careful consideration of various inelastic and transfer channels, with positive and negative Q-values, which couple to the entrance channel and contribute to the fusion cross-section[12]. This work is in progress.

References

(1) M. Beckerman et al., Phys. Rev. Lett. 45 (1980) 1472; Phys. Rev. C28 (1983) 1963 and references therein.

(2) W. Reisdorf et al., Phys. Rev. Lett. 49 (1982) 1811.
R.G. Stokstad et al., Z. Physik A295 (1980) 269.

(3) R. Pengo et al., Nucl. Phys. A411 (1983) 255.

(4) C.Y. Wong, Phys. Rev. Lett. 31 (1973) 766.

(5) L.C. Vaz et al., Phys. Rep. 69 (1981) 373.

(6) A.M. Stefanini et al., Phys. Rev. C30 (1984) 2088.

(7) S. Beghini et al., submitted to Nucl. Instr. and Meth.

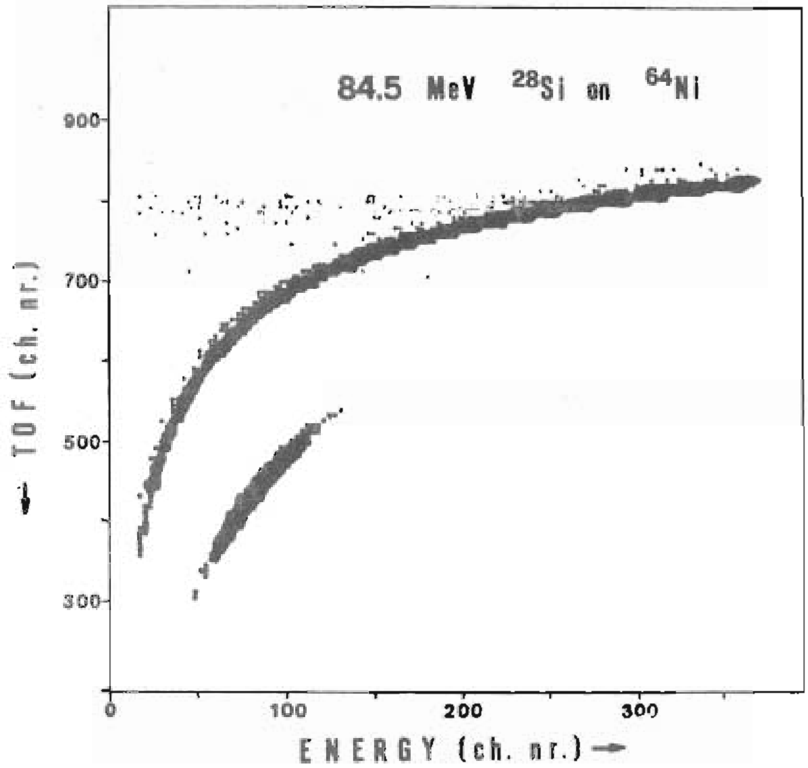

Fig. 1

Scatter plot of events measured at 0° for the indicated reaction. The evaporation residues are the lower island of events.

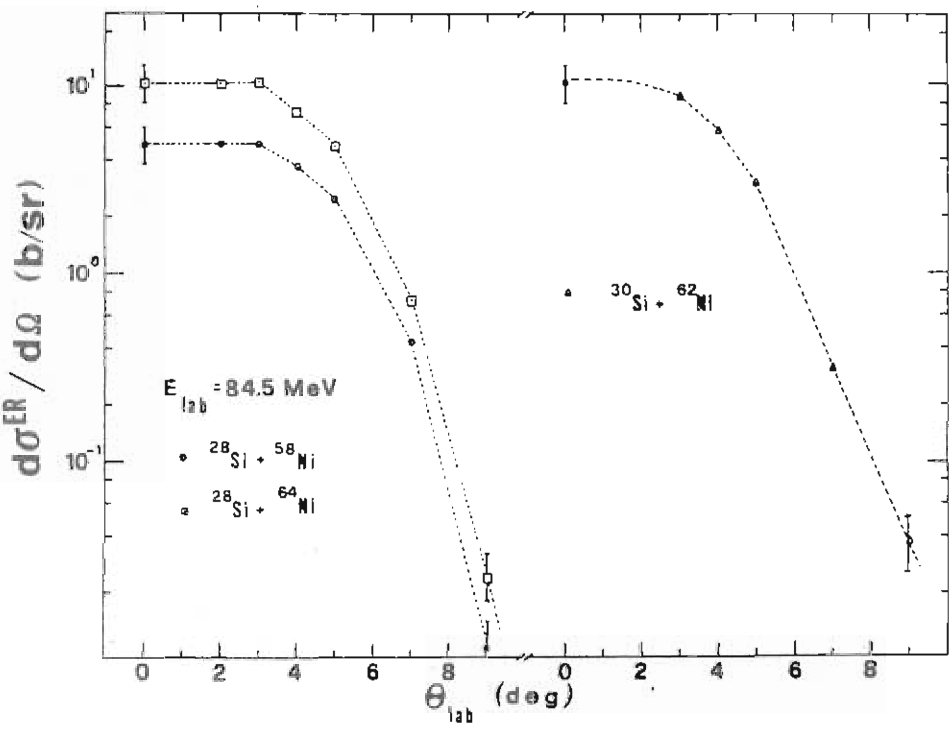

Fig. 2. - Evaporation residue angular distributions for some of the studied systems. The lines are drawn to guide the eye.

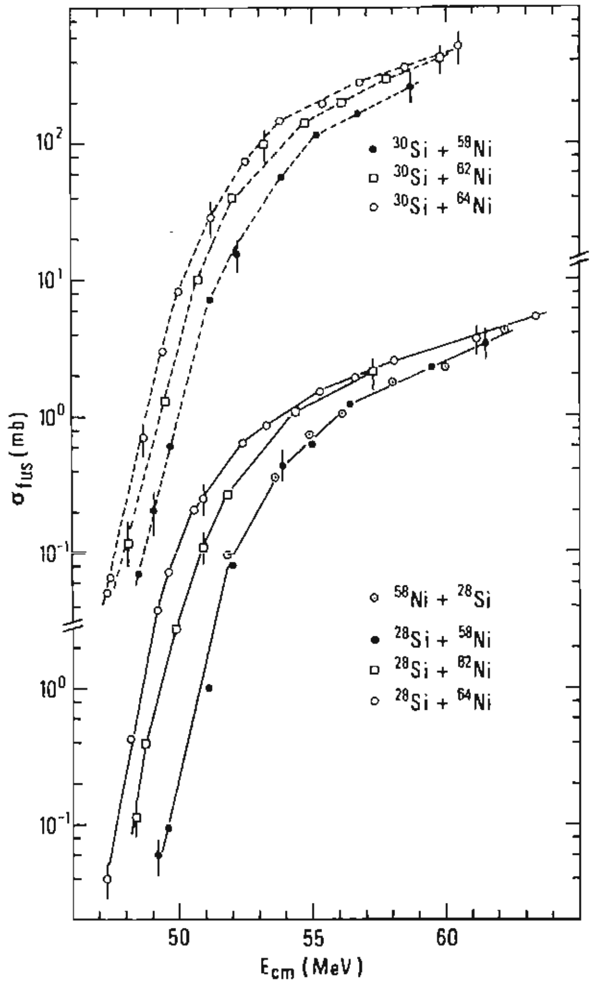

Fig. 3

Fusion cross sections for the various Si+Ni systems. Full and dashed lines are drawn through the experimental points as visual guides. Error bars are reported in a few representative cases.

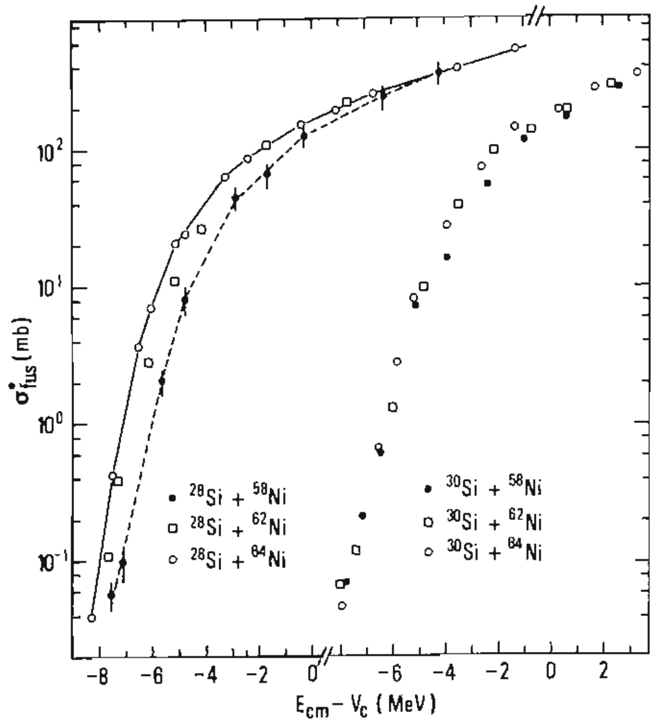

Fig. 4

Reduced fusion cross sections plotted vs. the energy distance from the classical barrier $V_C = Z_1 Z_2 / (A_1^{1/3} + A_2^{1/3})$. The quantity along the ordinate is $\sigma^*_{fus}(A_1,A_2) = \sigma_{fus}(A_1,A_2) *$ $* [28^{1/3} + 64^{1/3}]^2 / (A_1^{1/3} + A_2^{1/3})^2$.

NEAR- AND SUB-BARRIER FUSION OF $^{32,34}S$ WITH $^{58,64}Ni$

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Experiments are in progress to study the fusion mechanism of medium-heavy nuclei around and below the Coulomb barrier. These studies are motivated by the recent experimental discoveries[1] of large cross sections with anomalous isotopic dependences in that energy range.

These studies use an electrostatic beam separator[2] to detect evaporation residues at and around 0° (see the preceeding contribution to this Annual Report).

The experimental results for two of the recently studied S-induced reactions are shown in fig. 1, where fusion cross sections are plotted vs. centre-of-mass energies; typical experimental errors are reported for one system. Also shown in the figure (dashed lines) are the calculations of one-dimensional barrier tunnelling, using Wong's formula[3] with $\hbar\omega$=3.8 MeV. Barrier heights and radii were taken from the phenomenological systematics of Vaz et al.[4]. The calculations underestimate the measured cross sections in the sub-barrier energy range by 1-2 order of magnitude, the enhancement being larger for $^{32}S+^{64}Ni$. The picture is similar for the ^{34}S-induced reactions (not reported here).

Fig. 2 shows reduced excitation functions for the four S+Ni systems: the abscissa is the centre-of-mass energy scaled by the barrier height. The two barrier parameters were obtained by fitting the cross sections with the "sharpcutoff" formula in the $200<\sigma<600$ mb range. The fusion probability of $^{32}S+^{64}Ni$ below the barrier is 20-30 times larger than for the other three systems, whose excitation functions are bunched together.

The picture which stands out from the data is in agreement with previous experiments[1,5]: the common enhancement of all cross sections is probably due to the coupling[6] of the entrance channel with reaction (inelastic and/or transfer) channels. The peculiar behaviour of the $^{32}S+^{64}Ni$ excitation function clearly shows the particular enhancement caused by the availability of large, positive Q-value reaction channels; the $^{64}Ni(^{32}S,^{34}S)^{62}Ni$ reaction has Q=+3.56 MeV, whereas all other systems have transfer Q-values either negative, or positive but small (Q<0.5<MeV). The dashed-dotted lines in fig. 1 are the results of coupled-channel calculations including the excitation of the first 2^+ levels of the two nuclei in the constant coupling approximation. The B(E2) values were taken from the literature and the barrier parameters from ref. (4). The data are reproduced satisfactorily only for $^{32}S+^{58}Ni$. The similarity of all excitation function slopes at the very low energy seems to indicate pure tunnelling through

barrier(s) lowered by the channel couplings. The same feature was observed in the Si+Ni systems[5]. The experimental slopes are in rather good agreement with the calculations (fig. 1) which use a barrier thickness very near to the value $\hbar\omega$=3.9 MeV (predicted e.g. by a proximity potential).

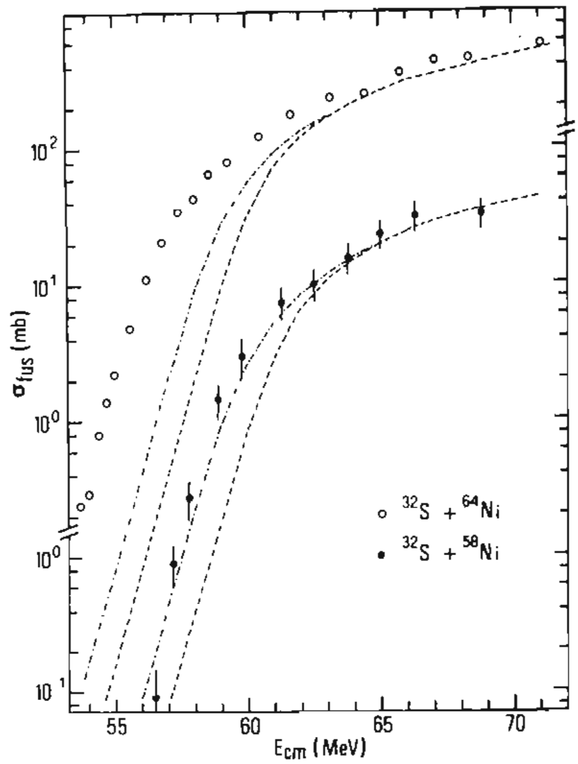

Fig. 1

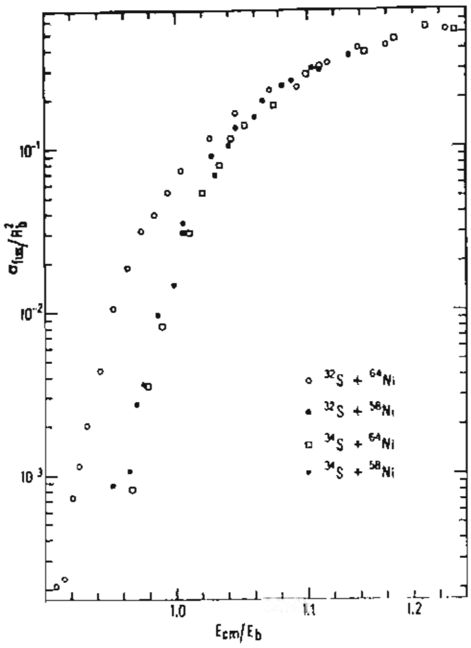

Fig. 2

References

(1) M. Beckerman et al., Phys. Rev. C25 (1982) 837.
(2) S. Beghini et al., submitted to Nucl. Instr. and Meth.
(3) C.J. Wong, Phys. Rev. Lett. 31 (1973) 766.
(4) L.C. Vaz et al., Phys. Reports 69 (1981) 373.
(5) A.M. Stefanini et al., Phys. Rev. C30 (1984) 2088.
(6) C.H. Dasso et al., Nucl. Phys. A405 (1983) 381.

- THEORETICAL NUCLEAR PHYSICS -

GAMMA DECAY OF THE GIANT RESONANCES

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The gamma-decay of the isoscalar giant quadrupole resonance (GQR) and of the isoscalar giant hexadecapole resonance (the N=2 component, GHR) of ^{208}Pb to the low-lying octupole vibration (3_1^-) has been calculated[1] in the surface coupling model[2]. A marked quenching of the transitions is observed arising from the correlation between the particle and the hole participating in the vibration, and from the coupling to the giant dipole resonance. The total Γ_γ (GQR→3_1^-) is found to be only a few percent of Γ_γ (GQR→ground state) consistent with the esperimental data recently obtained in heavy ion reactions[3]. The compound nucleus gamma-decay is estimated to be negligible. The strength functions associated with the GQR and GHR used in the calculations are displayed in fig. 1.

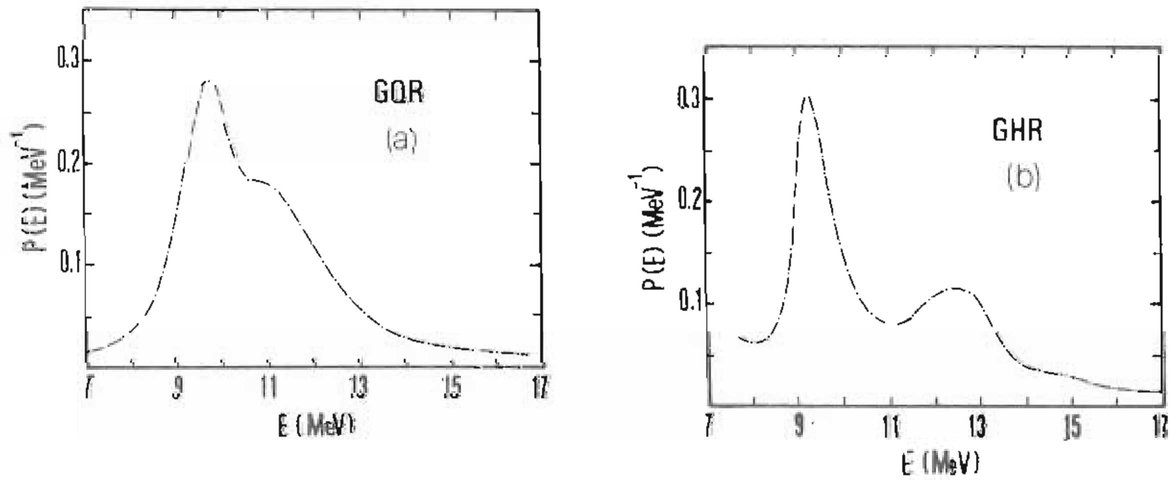

Fig. 1. - Adapted from ref. (1). Strength functions calculated in the surface excitation model and associated with the GQR (a) and GHR (b).

References

(1) P.F. Bortignon, R.A. Broglia and G.F. Bertsch, Phys. Lett. **148B** (1984) 20.

(2) G.F. Bertsch, P.F. Bortignon and R.A. Broglia, Rev. Mod. Phys. **55** (1983) 283).

(3) F.E. Bertrand, J.R. Beene and J.P. Sjoreen, J. Phys. (Paris) **45** (1984) C4 99 and private communication.

DYNAMICS OF THE SHELL MODEL

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The abstract of the review article[1] on the dynamical content of the shell model in nuclei and in other Fermi liquids is reported:

"Many Fermi liquids are amenable to a shell model description, where the particles move in an average potential. The coupling of the single-particle degrees of freedom to other modes of excitation strongly affects the properties of the shell-model potential. It is empirically found, however, that these couplings preserve the approximate validity of the shell model. Significant theoretical progress has recently been accomplished in the understanding of the resulting "dynamical shell model" in nuclear matter, normal liquid ^{3}He, the electron gas and nuclei. The dominant modes which couple to the single-particle motion are particle-hole excitations in the case of nuclear matter, paramagnons in the case of ^{3}He, phonons for electrons in metals and surface vibrations in the case of nuclei. For the latter, the dynamical shell model can be viewed as an extension of the optical model to encompass both positive and negative energies. It thus provides a unified description of scattering and of bound single-particle states. The associated potential is energy dependent. This feature is characterized by the nucleon effective mass. The theoretical and experimental evidence which testifies to the existence of a strong energy dependence of this effective mass around the Fermi energy and near the nuclear surface is the central subject of the present review.

References

(1) C. Mahaux, P.F. Bortignon, R.A. Broglia and C.H. Dasso, Phys. Reports, in press.

THE COLLECTIVE PAIR APPROXIMATION

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The description of well-deformed nuclei in terms of a condensate of collective fermion pairs defined in the intrinsic frame is reviewed. Low-lying excited bands are naturally described as "one-broken pair" states, while the usual Nilsson-type quasiparticle spectrum in odd-A nuclei is directly obtained by coupling the odd particle to the pair condensate.

As an example the method is applied to the description of even Samarium and Neodinium isotopes and of the neighbour odd Promethium isotopes. The connection between the present (fully fermionic) approach and the Interacting Boson Model is discussed, with a special attention to the problem of the truncation of the expansion of different operators in the boson space.

References

(1) E.Maglione, A.Vitturi, F.Catara and A.Insolia: Phys. Lett. 137B (1984) 1; Phys. Rev. C29 (1984) 1916.

(2) E.Maglione and A.Vitturi: Nucl. Phys. A430 (1984) 158. Proc. of the Workshop on "Interacting Boson-Boson and Boson-Fermion Systems", Ed. O.Scholten, World Scientific Press, 1984 (in press).

STUDY OF THE SELECTIVITY DISPLAYED BY (^{6}Li,d) AND (^{16}O,^{12}C) REACTIONS

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Four-particle transfer reaction have been found to be very selective in exciting the nuclear spectrum. In many cases a rather clear correspondence between the states excited in the four- and two-particle-transfer reactions has been observed. A central question in nuclear structure is whether there exist elementary modes of excitation associated with the correlation of four particles. To this date no positive evidence has been obtained of such modes. On the other hand, while the strength with which these modes should be seen is simple to calculate, large uncertainties are ascribed to the predictions of the associated excitation energies.

Insight into the possible existence of α-vibration can be gained by comparison of studies carried out making use of projectiles in which the four particles to be transferred display different correlations. A first step in such a project is to determine whether different reactions populate well-known states with different selectivity. An opportunity to make progress in this subject is provided by the detailed measurements of (^{6}Li,d) and (^{16}O,^{12}C) reactions which have been carried out on two Fe isotopes at bombarding energy well above the Coulomb barrier.

In the present paper we carry out an analysis of the strongly excited 0^+ states, making use of microscopic form factors and setting special emphasis on the nuclear structure aspects of the observed cross sections.

References

F.Catara, A.Insolia, E.Maglione, A.Vitturi and R.A.Broglia, Nucl. Phys. A424 (1984) 184.

TWO- AND FOUR-PARTICLE SURFACE CLUSTERIZATION IN DEFORMED NUCLEI

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We study the problem of the influence of the pairing interaction on two- and four-particle surface correlations in deformed nuclei. Taking the overlap between the two- or four-particle wave function in a di-nucleon or alpha-particle wave function, respectively, one obtains cluster probability distributions, as functions of the center-of-mass coordinate of the considered particles. For particles moving in pure Nilsson orbits the probability is localized in the intrinsic frame in different region of the nuclear surface, according to the K-quantum numbers of the considered orbitals. The inclusion of the pairing interaction leads to a probability distributed over the entire surface but at the same time to values of the total spectroscopic factors orders of magnitude larger than those associated with pure Nilsson orbits.

References

F.Catara, A.Insolia, E.Maglione and A.Vitturi, Phys. Rev. C29 (1984) 1091; Phys. Lett. 149B (1984) 41.

Proceedings of the Int. Conf. on "Clustering Aspects of Nuclear Structure and Nuclear Reactions", Chester, 1984, Contributed Papers.

- APPLIED NUCLEAR PHYSICS -

CHECK OF HELIUM IMPLANTED IRON AND GADOLINIUM FOILS WITH THE BACKSCATTERING TECHNIQUE

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Helium implanted targets can be very useful when performing inverse reactions at the LNL XTU Tandem and in particular for the study of the transient magnetic field at high recoil velocity. Then their characteristic should be carefully checked.

We report here backscattering measurements with proton and alpha beams on the iron and gadolinium targets used in the experiment of ref. 1. The He-implanted targets were prepared at the Strasbourg C.R.N. Laboratories using a 40 KeV beam.

For the investigation with protons, about 10 nA of 2.5 MeV particles were sent on implanted iron and gadolinium foils. The backscattered particles were detected at 138°. The differential cross-section in known to be 330 mb/sr (2). From the observed energy loss the gadolinium and iron thicknesses were found to be 2.5 mg/cm^2 and 1.24 mg/cm^2 respectively, assuming the Ziegler stopping powers (3). Using the Rutherford scattering yield as a reference, one gets the following estimates for thickness of the helium layers: $5(1)10^{17}$ at/cm^2 for Gd and $3(1)10^{17}$ at/cm^2 for Fe; i.e. about half of the declared implanted dose.

The adopted reaction is not very sensitive to the profile of implantation. Anyhow an order of magnitude could be extracted increasing the effective thickness by tilting the targets.

The derived mean depths and range stragglings of the implanted helium are 0.25 mg/cm^2 and 0.12 mg/cm^2 for Gd and 0.17 mg/cm^2 and 0.09 mg/cm^2 for Fe with an error of approximately 30%.

These values were further checked with alpha backscattering at 3 MeV. In this case the implanted helium is seen as a small saddle in the Rutherford plateau produced by the ferromagnetic host. By fitting the data assuming a gaussian distribution for the implanted helium one gets 0.23 mg/cm^2 and 0.12 mg/cm^2 in good agreement with proton data. The observed ranges and stragglings agree with the tabulated values (3), underlining that saturation effects are not yet important.

Moreover the profile of oxidation of the gadolinium target has been checked. In fact it could be possible that, due to the annealing procedure at 800° some superficial oxygen atoms penetrate deeply into the ferromagnet. For this check the resonance at 3.05 MeV in the $^{16}O(\alpha,\alpha')^{16}O$ reaction has been used. It turned out that the oxidation affects only the very first surface.

References

(1) D. Bazzacco, F. Brandolini, P. Pavan, C. Rossi Alvarez, R. Zannoni, K.H. Speidel, M. de Poli; contribution to this paper.
(2) L. Kraus and I. Linck; Nucl. Phys. A224 (1974) 45.
(3) J.F. Ziegler; The Stopping and ranges of ions in matter, Pergamon Press.

HIGH SENSITIVITY PIXE DETERMINATION OF SELENIUM IN BIOLOGICAL SAMPLES USING A PRECONCENTRATION TECHNIQUE

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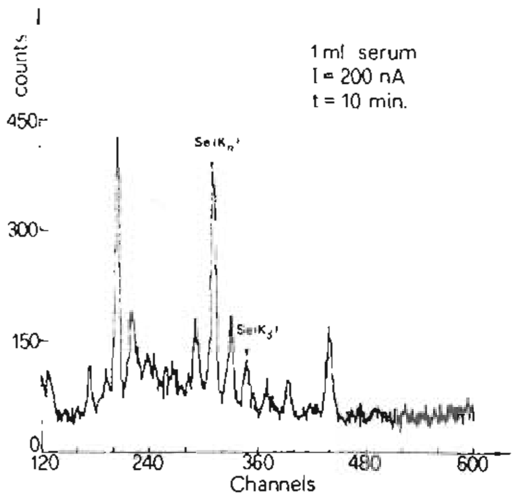
The importance of selenium in biological and organic matrices is well established; a very sensitive and fast analitical method is necessary to investigate its role deeply. A preconcentration technique is described that allows selenium detecting at the p.p.b. level in biological samples in a short time. It involves first the decomposition of the organic matrix and then the precipitation of selenium using tellurium both as the coprecipitant and as the internal standard. For serum samples the optimal range of volume to be used is 0.1-2 ml. The sensitivity is obtained at the p.p.b. level after about 10 min. irradiation time. The accuracy of the method is checked by comparison with the direct pelletization method and by using a standard reference material (see figures).

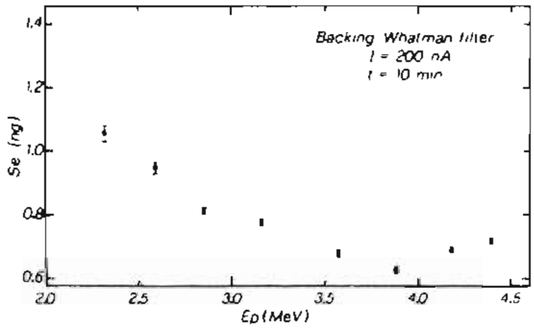
References

(1) G.P. Buso, P. Colautti, G. Moschini, Hu Xuscheng, B.M. Stievano; Nucl. Instr. Meth. 231 (1984) 177.

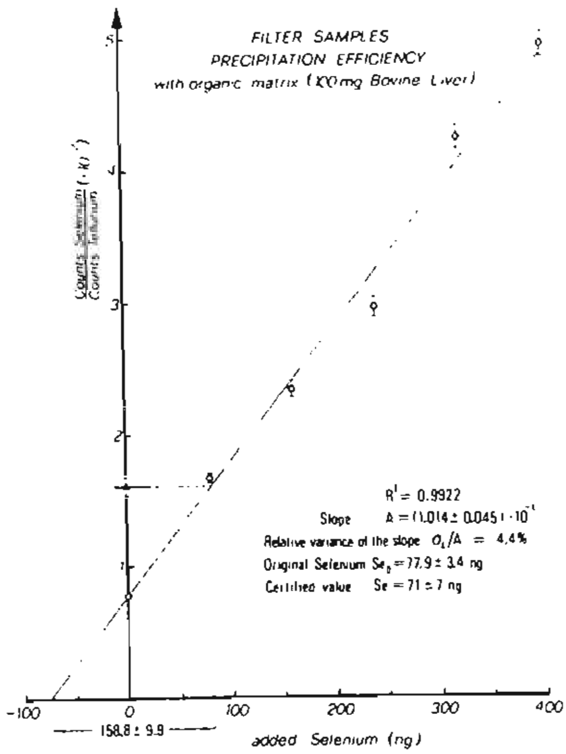
(2) G.P. Buso, F. Maggioni, G. Moschini, M. Saladini, G.Zanchin; XX Riunione della Sezione di Neuropatologia della S.I.N., Tarquinia (1984).



A portion of a serum spectrum.



Sensitivity versus proton energy.



Calibration curve for bovine liver NBS 1577 a.

HIGH-ENERGY MASS SPECTROMETRY WITH THE XTU TANDEM ACCELERATOR

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An Italian AMS (Accelerator Mass Spectrometry) program has been developed in which ^{10}Be and other rare radioisotopes will be measured for applications in different sciences like cosmochronology, geology, hidrology and medicine[1,2].

In the following we describe the current status of the AMS system which has been used for measurements on standard samples with known $^{10}Be/^{9}Be$ isotopic ratio[3].

^{10}Be ($T_{1/2}$=1.6×10^6y) is one of the cosmogenic nuclides produced in the interaction of cosmic rays with terrestrial and extraterrestrial matter that can be used as cosmochronometers and geophysical tracers. ^{10}Be is useful to study the modulation of galactic cosmic rays, irradiation history of meteorites, geomagnetic reversals, solar variability, volcanic recycling of subducted material and growth rate of deep-sea nodules.

Berillium is introduced in the sputter source as BeO; silver powder is added to improve the source emission.

The accelerator is operated at 10.7 MV during ^{10}Be measurements. The terminal voltage is regulated by the GVM control system since the current of mass 10 beam is too low for slit control. BeO^- is dissociated at the high-voltage terminal by N gas before stripping by a C foil; the addition of the stripper gas at a suitable pressure improves transmission by a factor of two. Both the abundant (^9Be) and the rare (^{10}Be) isotopes are analyzed in the 3^+ charge state.

As the beam intensity differ by a factor 10^9 or more, different methods are used to detect the two isotopes. ^9Be beam is transmitted only as far as the image position of the 90° analyzing magnet and it is measured by integrating the current in the Faraday cup. The inflection magnet, the analyzing magnet and the high-energy quadrupole are then scaled to transport ^{10}Be and the Faraday cup is retracted. The rare isotope is transmitted to the final detection system after a further deflection (50°).

The transmission of the whole beam transport system is optimized beforehand by injecting mass 25 (^9Be $^{16}O^-$) and analyzing $^9Be^{+++}$ at 12 MV. The beam sensitivity to terminal voltage fluctuations is reduced by narrowing the 90° image slits during this step, and then doubling their width for taking data.

The final separation of ^{10}Be from the interfering background is carried out by using a E-ΔE silicon telescope at 0°. A Zr absorber foil removes completely the isobar ^{10}B that mimics ^{10}Be in all acceleration and magnetic analysis step. ^{10}B is used as pilot beam (to check the tuning of the accelerator before starting ^{10}Be measurements and then to monitor the stability of the transmission) by measuring ^{10}B scattered by a gold foil in a silicon detector at 30° with respect to the beam direction.

We have measured three standards of known $^{10}Be/^{9}Be$ isotopic ratio (obtained by repeated dilution of a stock solution). Fig. 1.shows the $^{10}Be/^{9}Be$ counting rate ratio measured by AMS vs $^{10}Be/^{9}Be$ atom ratio determined by β-counting. The quoted error (7.7%) is the standard deviation determined by repeated measurements of the same sample. Fig. 2 shows a E-ΔE spectra obtained from one of these standards ($^{10}Be/^{9}Be=7.27\times10^{-11}$). The average background counting rate of ^{10}Be obtained from a pure reagent BeO is 0.01 cps, corresponding to an atom ratio $^{10}Be/^{9}Be$ $=5\times10^{-13}$.

The sensitivity,accuracy and linearity obtained are already satisfactory. Further modifications are in progress to extend the capability of the system.

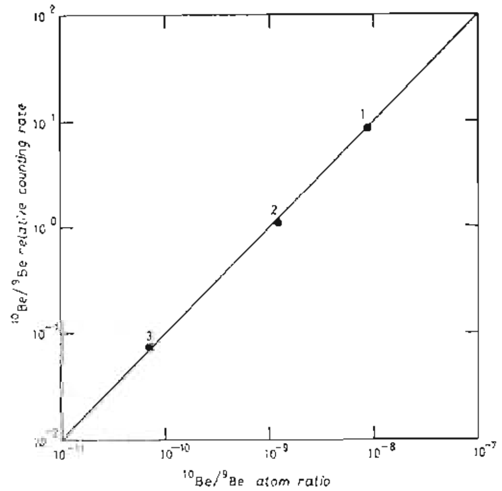

Fig. 1

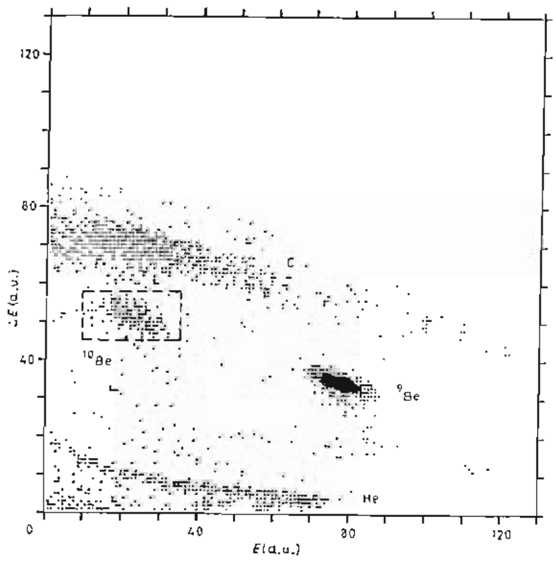

Fig. 2

References

(1) G. Moschini, B.M. Stievano, Fisica in Medicina, Vol. IV, n. 1.

(2) C. Tuniz, LXX Congresso Nazionale S.I.F., Genova 1984.

(3) C. Tuniz et al., Il Nuovo Cimento, Vol. 84B, n. 2, p. 121.

EXTENDED SOLID SOLUTION OF Fe IN Pt BY ION BEAM MIXING: ROLE OF ENERGY DEPOSITION AND EFFECT OF THERMAL TREATMENT

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A metastable solid solution of Fe in Pt with 40 at.% Fe has been obtained by 200 keV Kr^{++} ion bombardment on a Si supported Fe-Pt bilayer structure having Pt as top layer. On the contrary when Fe is used as top layer the induced mixing does not produce a phase with definite stoichiometry. This different behaviour is discussed in terms of enhanced diffusion processes influenced by the energy deposition distribution in atomic processes. The effect of the thermal treatment has been investigated both on the extended solid solution produced by ion bombardment and on the unirradiated Fe-Pt bilayers.

ENHANCED DIFFUSION PROCESSES IN Ar^+ IMPLANTED ALKALI-CONTAINING GLASSES

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Heavy ion implantation into alkali-containing glasses induces an alkali migration which can be interpreted on the basis of an enhanced diffusion process over the range of the implanted ions.

Room temperature implantations of 50 and 90 keV Ar^+ in $12\ M_2O \cdot 88\ SiO_2 (M = K, Rb, Cs)$ and $16\ K_2O \cdot 78\ SiO_2 \cdot 4\ Al_2O_3 \cdot 2\ MgO$ glasses induce an alkali depletion up to a depth which is not dependent on the element, but is directly connected to the actual Ar^+ ion penetration depth. Alkali profiles in the implanted region depend on the element and on the overall composition of the glass.

Similar implantations on $(12-x)K_2O \cdot xCs_2O \cdot 88\ SiO_2 (x=3,6,9)$ and $(16-x)Na_2O \cdot xK_2O \cdot 78\ SiO_2 \cdot 4\ Al_2O_3 \cdot 2\ MgO (x=6,10,12)$ show that the depletion of the heavier element of the couples Cs-K and K-Na is linearly dependent on its molar concentration and that the depletion depths are not influenced by the presence of K and Na respectively. On the contrary in the case of the K-Na mixed-alkali glass the Na depleted layer thickness depends on the relative alkali content, indicating an interaction between the alkali ions during the enhanced diffusion process.

HYDRATION OF ION IMPLANTED SILICA: EVIDENCE FOR HYDROGEN TRAPPING ON DEFECTS

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Hydration of ion implanted vitreous silica leached in deionized water at 100°C has been studied by performing hydrogen depth-profiling by means of the resonant nuclear reaction $^{1}H(^{15}N,\alpha\gamma)^{12}C$. Thermal annealing prior to leaching has been used to evidence the possible role of radiation damage. We show that the H-profile reflects the damage distribution and is modified by thermal annealing in a way which can be readily interpreted in terms of annealing of defects, where extended defects seem to play the dominant role. It is therefore concluded that H-uptake occurs via trapping on defects.

NEW DATA ON ION-INDUCED MODIFICATIONS OF AQUEOUS DISSOLUTION OF SILICATES

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The ion-induced modifications of aqueous dissolution have been thoroughly investigated in several silicates (amorphous silica, quartz, soda-lime glass and albite) by applying depth profiling techniques (RBS and resonant nuclear reactions) for the characterization of leached surfaces. We show in particular that the H penetration after implantation and leaching is markedly increased when the ion dose exceeds a critical value comprised between 10^{13} and 10^{14} $Pb\cdot cm^{-2}$. This feature supports the radiation damage origin of the observed effects. Such experiments provide interesting clues about the aqueous dissolution of silicates and show that no important effect of α-decay is expected on the hydration of HLW glasses during disposal.

TRANSFORMATION TO AMORPHOUS STATE OF METALS BY ION IMPLANTATION: P IN Ni

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The amorphization of Ni single crystals by P ion implantation was studied via in situ Rutherford backscattering and channeling experiments. Both the P-implant and the Ni-disorder profiles were analyzed. At 90 K, no P mobility was found under implantation. The fluence dependence of the disorder level is analyzed in terms of amorphous-cluster formation above a threshold P concentration. The radius of the clusters is four interatomic distance, i.e., the correlation length of a typical amorphous lattice as determined in structure-sensitive experiments. The amorphous fraction α in the implanted layer is $\alpha=0.5$ when $x \sim 0.12 (Ni_{1-x}P_x)$ and $\alpha=1$ when $x \sim 0.15$. At 300 K, short-range P motion occurs during implantation. Amorphous clusters are formed even at low P concentrations ($x \sim 0.05$). The P-to-Ni ratio in the clusters is that of the eutectic, and we found $\alpha=1$ at the eutectic composition. There is evidence that the amorphization mechanism described in this paper also holds for other metal-metalloid systems.

A NEW FACILITY FOR RADIOBIOLOGICAL STUDIES AT CN ACCELERATOR

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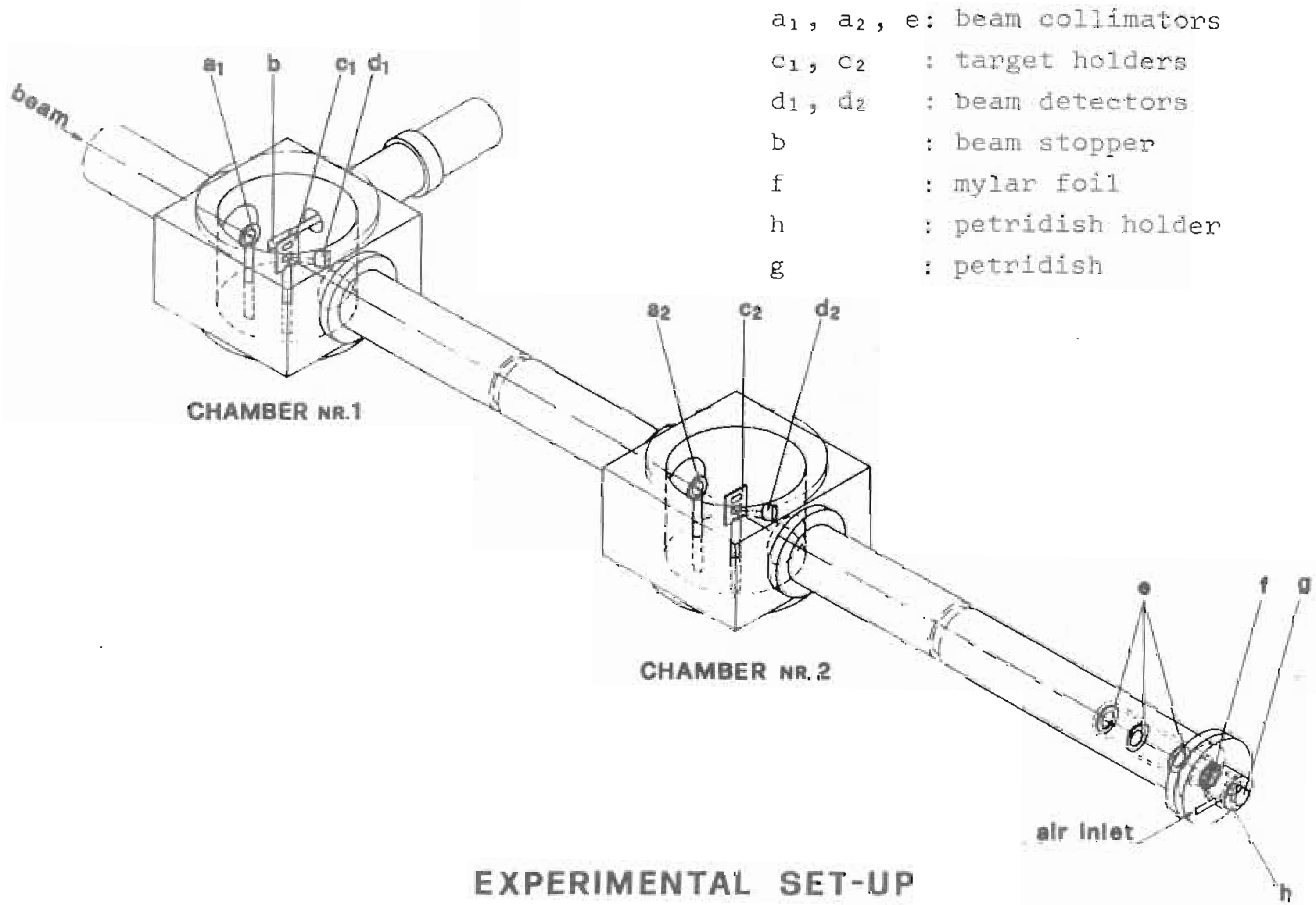
Particle beams are widely used in the medical fields for therapeutic purposes. Compared to electromagnetic radiation, accelerated particles offer many advantages, such as a well defined range and the maximal energy transfer at the end of their track (Bragg peak). This fact is of great importance for therapeutical purposes, where the applied dose should be focused to a well defined volume. Chemical effects, and therefore biological responses, depend strongly on the number of liberated electrons in a small critical target volume such as a cell, its nucleus or the DNA within it; on the other hand the track diameter and the electron density is determined by the energy of the primary particles. Of particular interest is the low energy range, near the Bragg peak. Taking into account this arguments, a low energy accelerator like CN accelerator is of particular interest when the radiobiological efficiency of proton and alpha particle beams near the Bragg peak is the main goal of the research.

For this purpose, a new dedicated beam line has been setted up, making possible air irradiation of living cells with uniform proton and alpha beam.

An uniformity better than 5% on a cross section of 110 mm^2 has been achieved (see fig. 1).

References

(1) M. Belli, S. Mazzuccato, M. Morando, G. Moschini, O. Sapora, M.A. Tabocchini:"Sopravvivenza e produzione di D.S.B. in cellule V79 irradiate con particelle ad alto LET"; 2° Convegno Società Italiana per le ricerche sulle radiazioni, Fermo (1984).



a_1 , a_2 , e: beam collimators
c_1 , c_2 : target holders
d_1 , d_2 : beam detectors
b : beam stopper
f : mylar foil
h : petridish holder
g : petridish

EXPERIMENTAL SET-UP

PLASMA DESORPTION SPECTROMETER

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A spectrometer for plasma desorption induced by 252 Cf source was developed.

The principle of operation is illustrated in fig. 1.

The particles emitted from the source pass through a time-zero detector based on Micro Channel Plate (MCP) and a target of biological material inducing the desorption of charged molecules. The particles are detected by a SSBD whereas the molecules are accelerated to 6÷10 keV and, after a flight path of 20 cm, impinge the surface of a MCP producing a stop signal.

Fig. 2 shows two time-spectra obtained with a $BaCl_2$ target; the first (A) was gated with the α particles of the 252 Cf source and the second (B) was gated with the fission fragments. Some not explained differences are evident. This method, introduced by Macfarlane[1], allow to measure molecular masses of some thousand a.m.u. and it is of great interest in biological and chemical study[2].

The desorption process itself is, up to now, not well understood[3] and the possibility to use the Tandem facility to vary the species and the energy of the projectile could be a valid tool in this kind of research.

References

(1) R.D. Macfarlane and D. Torgerson; Science 191 (1976) 920.

(2) P. Vigny et al.; Annual Report 1983-1984 Institut CURIE Lab. del Physique et Chimie Biomoleculaire (Paris).

(3) S. Della Negra, Y. Le Beyec; Nuclear Science Applications Vol. 1 (1983) 569.
J. Chaumount et al.; Nucl. Instr. and Meth. 229 {B1} (1984) 409.

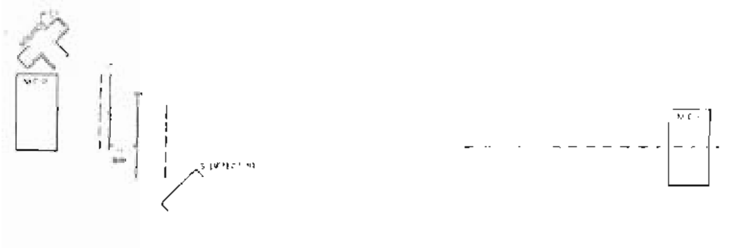

Fig. 1. - Mass spectrometer schematic.

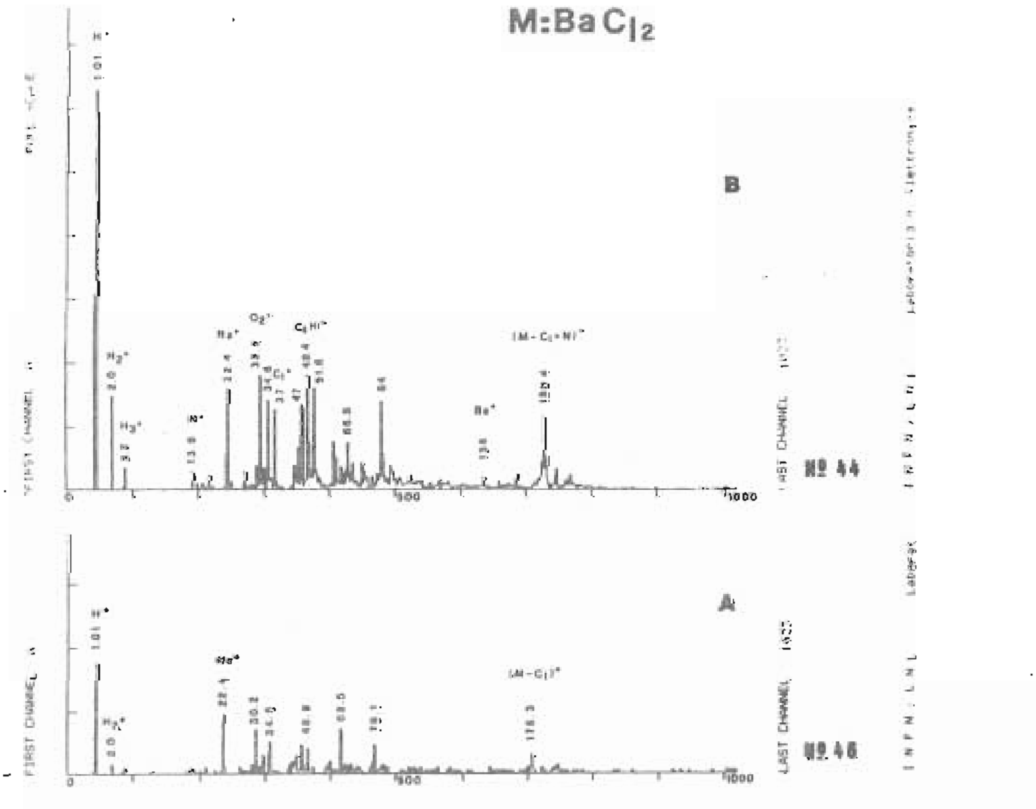

Fig. 2. - Mass spectra for a $BaCl_2$ target gated with α particles (A) and fission fragments (B).

TIMING PROPERTIES OF ULTRA-THIN SCINTILLATOR FOILS

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A systematic investigation on luminescence and timing properties of ultra-thin film detectors (1,2), with thicknesses ranging from 20 to 200 $\mu g/cm^2$, was undertaken in order to find the best conditions for this kind of transmission detector.

The light collection system, coupled to two selected and matched phototubes, provided an effective method for testing and comparing the properties of different scintillator foils. Typical responses to ^{252}Cf spontaneous fission fragments were analysed in two-dimensional contour plots, relating to (i) residual energy of the fragments vs time-of-flight; (ii) light output vs time-of-flight; (iii) light outputs vs residual energy.

In our study, we observed that the time response is not greatly influenced by the film thickness. The relative timing response may be observed directly from the "light output vs specific flight-time" contour plots, by considering the full-width at half-maximum (FWHM) of the two peaks, projected on the time axis (see Fig. 1 as a typical illustration). In Fig. 2 (a,b) are plotted the FWHMs corresponding to the high-and low-mass fragments $[\Delta(v_H^{-1}); \Delta(v_L^{-1})]$ as a function of foil thickness. A still more sensitive measurement of the timing properties can be made by considering the minimum specific flight-time interval $(v_H^{-1}-v_L^{-1})$ between the peaks at half-maximum, related to the corresponding peak distance at the maximum $(V_H^{-1}-V_L^{-1})$. In Fig. 2 (c) are plotted the $(v_H^{-1}-v_L^{-1})/(V_H^{-1}-V_L^{-1})$ ratios as a function of foil thickness.

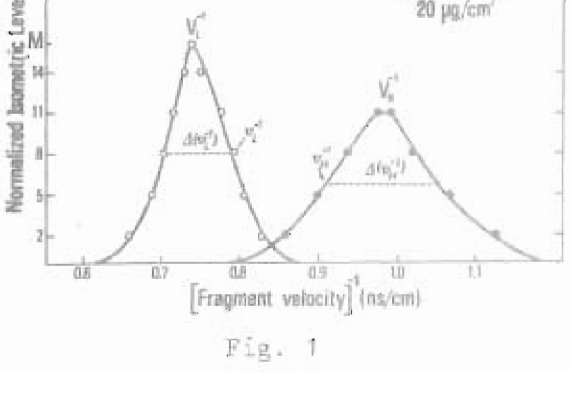

Fig. 1

It is interesting to notice that the quantities considered in Fig. 2 were so regular that they could be fairly fitted by straight lines. However, a large inconsistency is observed occasionally for different TFDs of similar thickness, suggesting a large variation in detector response. A reason for this maight be the inherent problem of consistentely producing detectors with the same properties.

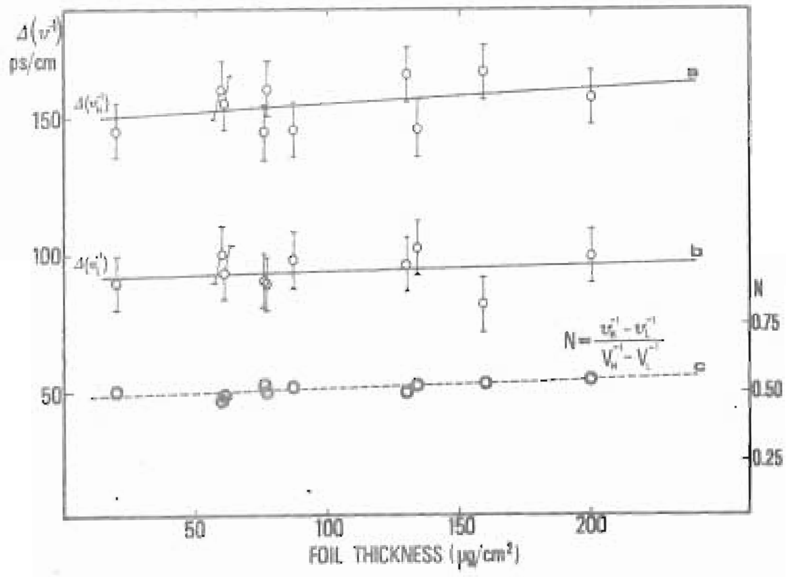

Fig. 2

References

1) P. Plischke, W. Scobel and R. Wien, Nucl. Instr. and Meth. 203 (1982) 419.

2) M.L. Muga and G. Griffith, Nucl. Instr. and Meth. 109 (1973) 289;
T. Batsch and M. Moszyński, Nucl. Instr. and Meth. 123 (1975) 341.

AN ANNULAR PARALLEL PLATE AVALANCHE COUNTER FOR HEAVY ION DETECTION

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The parallel plate avalanche counter (PPAC) has several advantages with respect to the solid state detector: it is insensitive to radiation damage, has a better timing and resistence to counting rate and can be built fulfilling any requirements of shape and area. For these reasons, when the energy resolution is not determinant, it is widely used in heavy ion detection .

We have developed an annular PPAC,which has been used for backward detection of heavy ions, following coulomb excitation in transient field g-factor measurements (1).

The detector has a sensitive area of 4 cm x 4 cm with a 10 mm central dead region and a central 3 mm hole.

As one can see in the figure, the detector consists mainly of three pieces, made from 1.5 mm thick plates currently used for printed boards. The entrance piece sustains the window, which usually consists of a 200 $\mu g/cm^2$ mylar foils. Few wires of 0.1 mm tungsten help to keep the foil. The second piece sustains a grid, consisting of 20 gilt tungsten wires, spaced 0.5 mm from each other and at 1.5 mm from the collector which is made from the third piece.

All these piece are glued together using a proper epoxy glue; the two small central annulus should be glued at the same time. We used a mask to center properly the pieces. Great accuracy is necessary when gluing the entrance window.

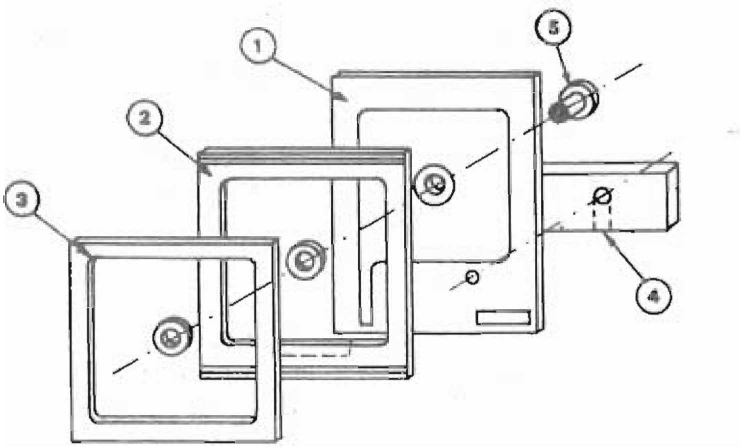
The mylar foil is first fixed to a 10 cm x 10 cm frame and then stretched on the entrance piece, when gluing.

In the collector piece two holes are made, which allow to maintain an isobutilene flux at about 10 mbar.

The complete detector assembly consists of the detector and of his connection to a flange which is then fixed to the cover of the scattering chamber.

A fast preamplifier like the one described in ref. 2 has been used, which has a gain of 500 and an output noise of 40 mV.

At an operating voltage of 450 volts for 20 MeV ^{32}S ions, one gets 1 volt pulse signal with 25% resolution and with 1.5 ns risetime.



1) collector piece; 2) grid frame; 3) window frame; 4) gas inlet; 5) centering annulus

References

(1) D. Bazzacco, F. Brandolini, P. Pavan, C. Rossi Alvarez, R. Zannoni, M. de Poli; contribution to this report.
(2) H. Steltzer; Nucl. Instr. and Meth. 133 (1976) 409.

STATUS OF RECOIL MASS SPECTROMETER PROJECT

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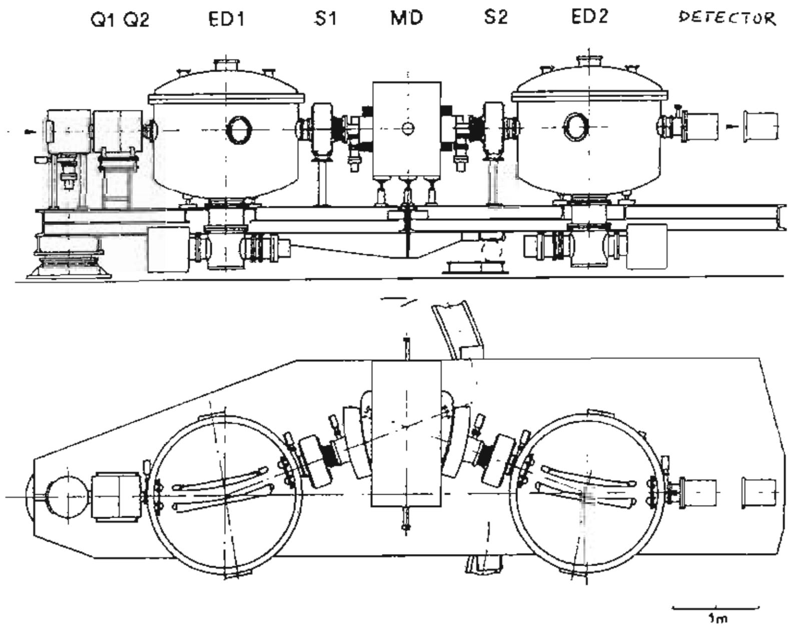
Calculations to define the L.N.L. Recoil Mass Spectrometer lay-out have been completed using the M.I.T. program RAYTRACE, modified at L.N.L.[1].

The initial implementation of the spectrometer will include 2 electrostatic dipoles, 1 magnetic dipole, 1 quadrupole doublet lens and 2 sextupole lenses (fig. 1).



In the future, improvements could be made by using multipole lenses instead of present pure quadrupole and sextupole lenses.

Specifications of the spectrometer are: solid angle acceptance >10 msr, energy acceptance ±20%, mass acceptance ±7%, mass dispersion 10 mm/% and mass resolution 1/280 at 5 msr and $\Delta E/E = \pm 10\%$.

Orders have been placed with the company Bruker Analytische Messtechnik for the three dipoles and the quadrupole doublet lens.

The construction design of the two electrostatic dipoles

+ *on leave from: Institute of Nuclear Research, Shanghai, China.*

has been completed and the production will start at the beginning of 1985. The electrode plates will have an area of about $0.6\times1.33\ m^2$ (anode) and $0.6\times1.28\ m^2$ (cathode) and a gap of 150mm.

The maximum voltage is expected to be around ±280 kV for routine operation at $|V|\leq 225$ kV on each plate (corresponding to a field of 30 kV/cm). The elctrode surface material will be titanium for both anode and cathode.

The vacuum system will include: a turbomolecular pump (1500 ℓ/s) and an ion pump (800 ℓ/s) for each electrostatic deflector, two 800 ℓ/s cryopumps for the section between the deflectors and two other 800 ℓ/s cryopumps for the target chamber and the focal plane detector.

The acquisition of all major components is anticipated for the end of 1985, so that the installation could start at the beginning of 1986.

References

(1) Report INFN/LNL 1983, p. 87.

- TECHNICAL DEVELOPMENTS -

A CAMAC DISPLAY CONTROLLER FOR THE DATA ACQUISITION SYSTEMS AT L.N.L.

G. Bassato

I.N.F.N., Laboratori Nazionali di Legnaro, Legnaro (Italy)

A CAMAC module for real-time display applications has been developed at L.N.L. Electronics Laboratory. This module is intended to work in conjuction with one - or more - CAMAC processor boards, based on MC68000 microprocessors[1]; these modules are linked together via a dedicated bus - basically a VME with some restrictions - on the front panel.

The display controller must be used with a magnetic deflection CRT; the graphic image is built by a "bit mapped" technique.

Basically the module contains a 32 Kb RAM memory (the display map), the CAMAC and the auxiliary bus interfaces, and a local arbitrator to share the memory access among the CAMAC, the auxiliary bus and the video control logic.

This module has been tested with a monochromatic CRT-21 kHz of horizontal frequency - obtaining a resolution of 640×400 pixel.

A new model, with the same design philosophy, but to be used with a colour monitor, will be developed within the current year.

References

(1) G. Bassato, Annual Report LNL, 1983.

C.A.P. - A COMPUTER AIDED PULSER

R. Bassini, P. Guazzoni, L. Zetta
INFN - Sezione di Milano
Dipartimento di Fisica - Universita' di Milano

In order to improve our identification system (1), we have designed and built a new kind of pulse generator, aided by a Vax computer.

This pulser, working as a digital to analog converter, can furnish up to four independent and coincident pulses, corresponding to the digital data stored in the computer memory. CAP is built in a standard two units NIM module. It is connected to the computer through a RS232C standard connection at 9600 baud rate. In this way it works as a passive peripheral, needing of a video to initialize the computer session and to activate the proper codes.

The general philosophy of the CAP system is the following. During an experiment, any kind of experiment, we can collect and store data, as coming from the detectors, on a magnetic tape. This is the first step of the data base. After it can be copied into the computer memory, with the data properly organized to build the final data base for CAP. At this point, using the CAP library -ad hoc written- we can send to the pulser, in serial mode, the digital data. An UART component provides to store in an input latch -in parallel mode- the first data. Subsequently it will be stored in an another latch, and so on for the other three data. When the four latches are filled, all the data are transferred to the 4 DAC and after to the proper output circuit to obtain an usefull analog shape of height corresponding to the digital value.

The first data base collected for CAP testing comes from the reaction 12C+26MG at 93.24 MeV incident energy measured at the Legnaro XTU Tandem. As preliminary result in fig.1 is shown the identification spectrum, obtained off line with the identifier of ref.1, using this data base. The output elements,from left to right, are: Li, Be, B, C, N, O. The laboratory angle was 10 degrees and the thin detector thickness 30 um.

REFERENCES

(1) P. Guazzoni, P. Michelato, A. Moroni, G.F. Taiocchi and L. Zetta - Nucl. Instr. and Meth. 200 (1982) 323

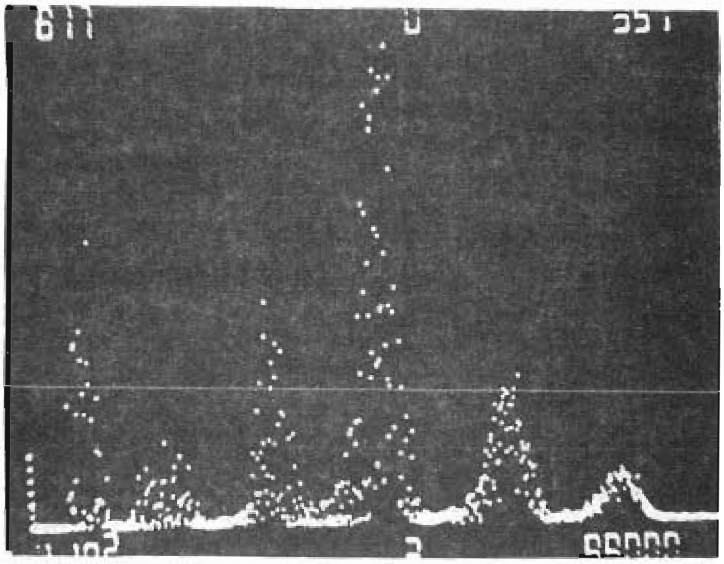


Fig. 1

AN ELECTRONIC APPARATUS FOR THE BRAGG-CURVE ANALYSIS

R. Bassini°, I. Iori°, A. Moroni°,
F. Gramegna*, G. Prete*, G. Viesti*

° *I.N.F.N., Sezione di Milano (Italy)*
* *I.N.F.N., Laboratori Nazionali di Legnaro, Legnaro (Italy)*

An electronic device[1]) dedicated to the analysis of the anodic signal of axial ionization chamber[2,3]) has been constructed.

The appartaus is a compact, simple to use, flexible and low costs device for the Bragg-signal handling. Coincident output pulses (total energy, Bragg-peak, energy loss and range) and the possibility of coincidences with other detectors are assured.

All these peculiarities are important especially in view of a large solid angle multichamber detecting system.

The Bragg-signal analyser (BSA) has been tested at the L.N.L. Tandem facility and compared with standard electronics using 143 MeV ^{32}S beam and Au, Al, Ni targets of different thickness.

The energy resolution values for these targets are 0.73, 1.4, 1.6% respectively. Similar results have been obtained with the standard preamplifier-amplifier chain. Only for the elastic scattering on Gold a slightly better value (0.62%) has been measured.

The Z-resolving power, using the Bragg-peak information, is $Z/\Delta Z=55$ for projectile-like fragments. These values refer either to the BSA or to the standard amplifiers with 0.25 μsec shaping time.

Introducing an RC integration in the BSA or using 0.5 μsec in the standard chain, $Z/\Delta Z$ values up to 78 have been obtained.

The energy loss and range resolutions are 2-3% and 3-4% respectively. The corresponding values for standard modules are 2.5-3% and 1.5-3%. The last result suggests the need of some improvement in the timing section of the BSA.

The preamplification section of the BSA works normally only up to 2.5 kHz and its performances have to be improved.

It has to be noticed that the chamber tests have shown good performances up to 20 kHz ($\Delta E/E<1\%$, $Z/\Delta Z<50$ for standard electronics).

Finally the Bragg-signal handling has been faced also using a waveform digitizer: a prototype is in progress.

References

(1) R. Bassini et al., Report INFN/TC - 84/23.
(2) A. Moroni et al., Nucl. INstr. and Meth. 225 (1984) 57.
(3) G. Prete et al., Nuovo Cimento 81A (1984) 208
(4) A. Moroni et al., Winter Meeting, Bormio 1984, p. 444.
(5) G. Prete et al., Nucl. Instr. and Meth., in press.
(6) A. Moroni et al., Bollettino S.I.F. 133 (1984) 54.
(7) A. Moroni et al., Lett. Nuovo Cimento 40 (1984) 321.

A DUAL PORT CAMAC MEMORY

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A dual port CAMAC memory for data acquisition of single and multiple parameters events in nuclear physics experiments has been realized at L.N.L. electronics laboratory.

The memory is accessible by two ways: through the standard CAMAC DATAWAY and through an additional "VME-like" bus on the front panel, implemented in order to link the memory to the CAMAC processor boards (based on MC 68000) developed at L.N.L.

The module is constituted by a board with control functions and by a memory array board.

The control board performs the following functions:

(a) interface to CAMAC bus with input and output buffer to synchronize the access operation on the internal bus that is a typical asynchronous bus;

(b) interface to reduced frontal VME bus with related memory base address and dimension acknowledgment logic;

(c) interface to auxiliary bus that connects the controller with memory array boards;

(d) timings generation and arbitration of internal bus access requests generated by CAMAC, VME-like bus and refresh logic;

(e) generation, by a Hamming modified code, of a six bits pattern to correct the single bit error and to detect all double bits error and some triple bits errors.

The memory board is constituted by an array of 88 chips of 64k bits dynamic RAM organized in a 4 banks of 64K words each one of 22 bits; 16 of such bits form the data word, while the remaining 6 are used by error detection and correction logic.

The number of memory boards that it is possible to connect to each memory control board can range from 1 to 32 and the corresponding memory size is from 512K bytes to 16 M bytes covering the full addressing capability of a 24 bits address.

PREAMPLIFIERS TEST

G. Prete, C. Baiocchi

I.N.F.N., Laboratori Nazionali di Legnaro, Legnaro (Italy)

A test was performed using the hybrid preamplifiers mod. 5242 (transistor input) and mod. 5254 (JFet input) developed by LABEN[1]. The used set-up is reported in fig. 1.

Using a Silicon Surface Barrier Detector of 50 mm^2 active area and 100 μm thick (15 keV FWHM) and a α-source of 241 Am (5.486 MeV) the obtained resolutions were:

100 keV with mod. 5242

26 keV with mod. 5254.

Fig. 2 reports the linearity of the electronic chain using the preamplifier mod. 5254.

In fig. 3 are shown the FWHM and Rise-time vs input capacitance characteristics of LABEN 5254, ORTEC 142 IH and ESN VV 10$\overline{0}$1 (developed by G.S.I.).

Quite attractive features of the LABEN 5254 are evident in the high capacitance region. It must be stressed the very low price of these preampliers ranging from 20.000 to 50.000 Lit.

(1) LABEN, via Bassini, 15, 20133 Milano (Italy)

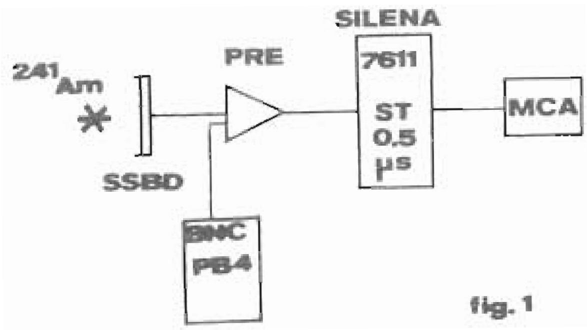


Fig. 1. - Electronic set-up.

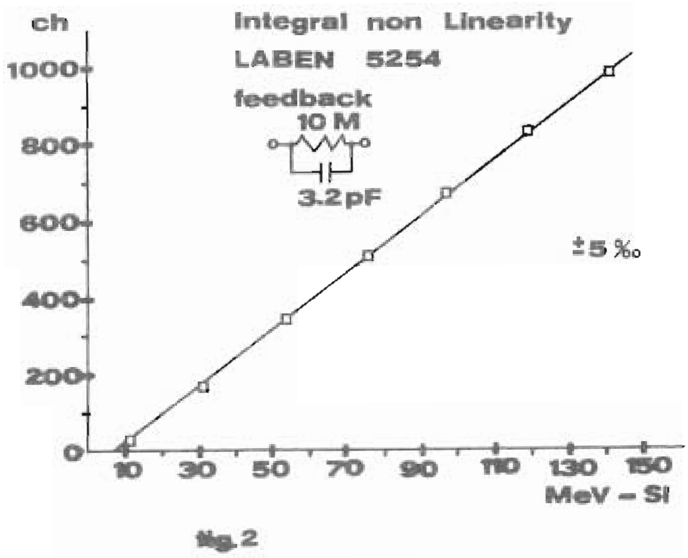
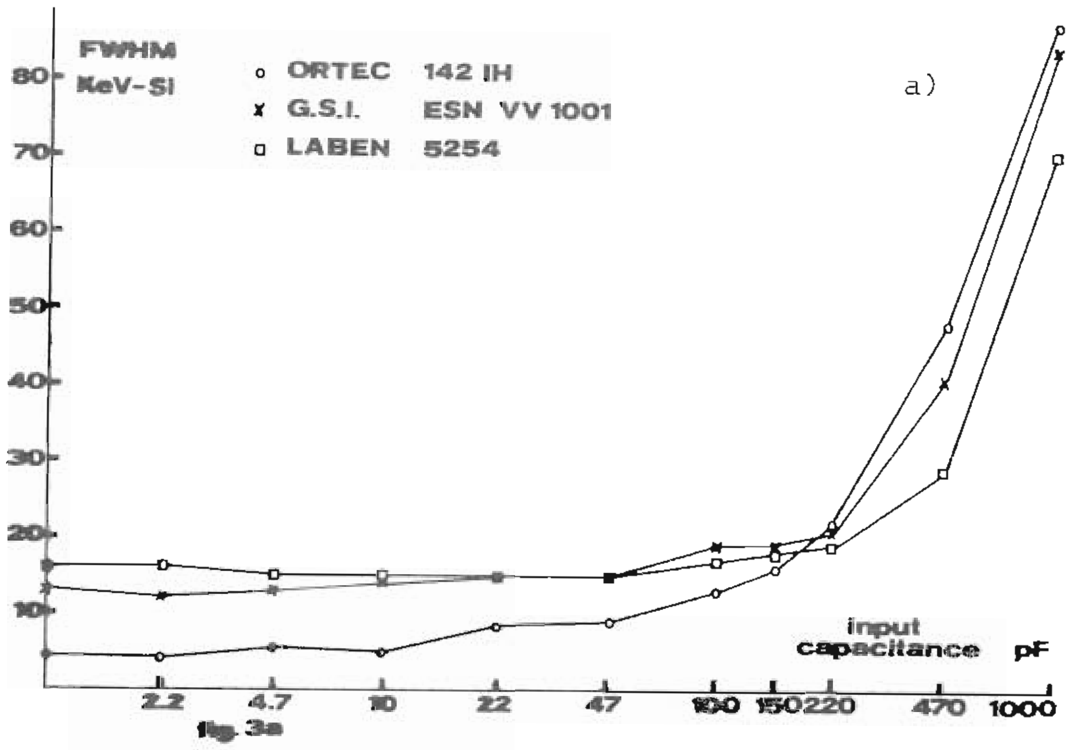


Fig. 2. - Measured integral non-linearity using the LABEN 5254 preamp.



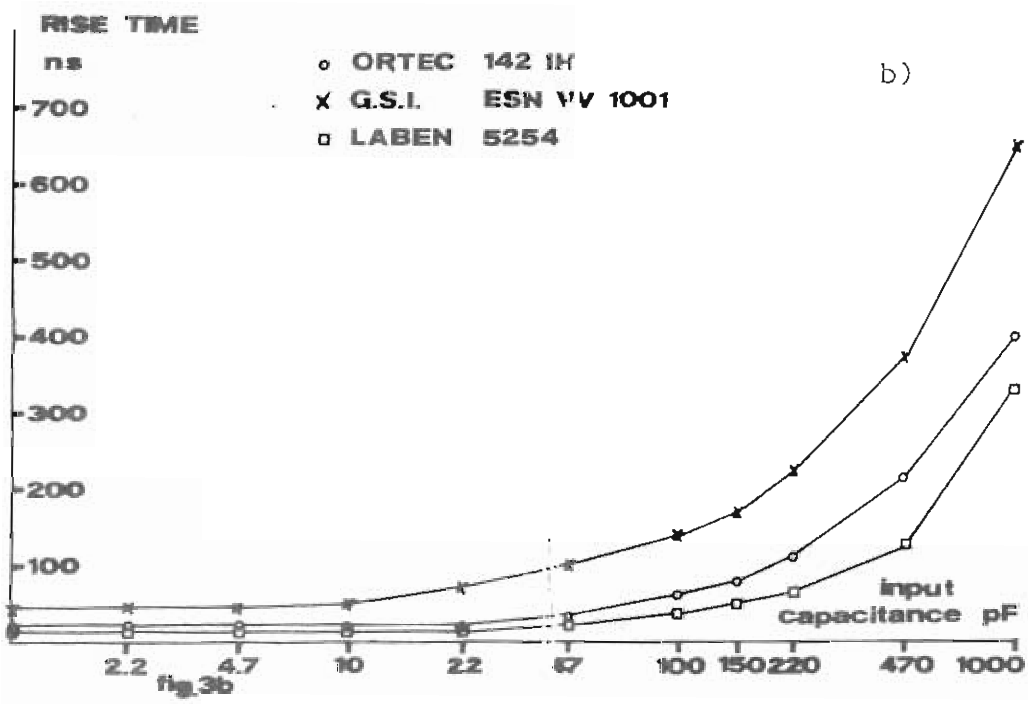


Fig. 3. - Energy resolution (3a) and rise time (3b) vs input capacitance for ORTEC 142IH, LABEN 5254 and ESN VV1001 amplifiers.

GENERAL PURPOSE INTERFACE TO CONNECT A MULTICHANNEL ANALYZER TO VAX COMPUTER

A. Zanon

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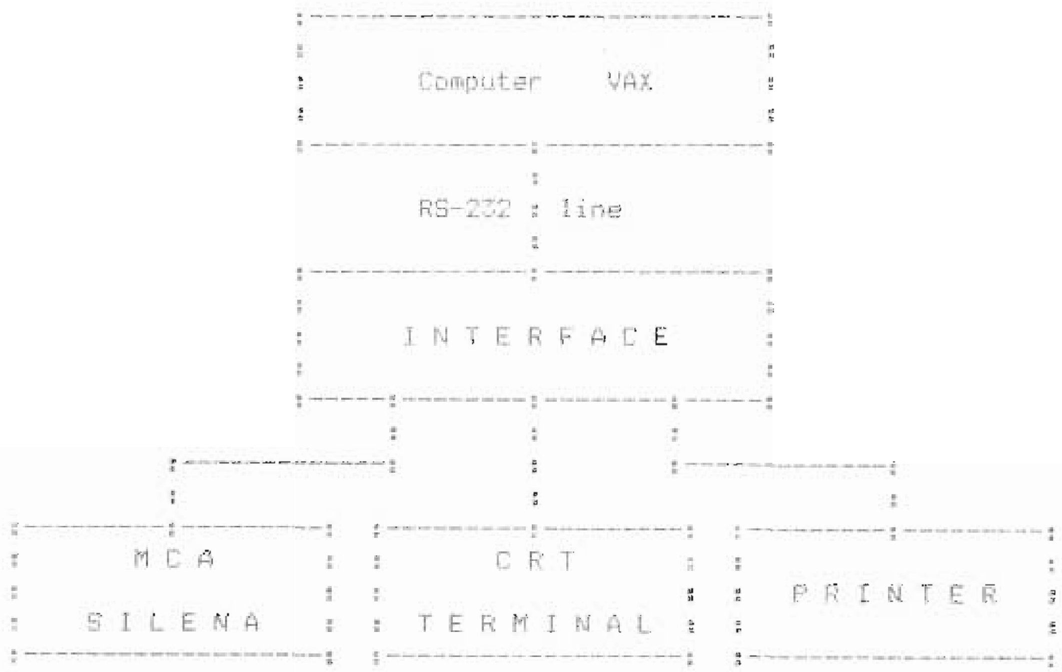
Some general purpose interfaces between VAX and MCA, terminal, printer have been made.

The hardware fo these devices is an "on board computer" designed by A. Fois fo the electronics laboratory of L.N.L.

A scheme of a typical configuration is drawn below.



The interface communicates with the computer through a dual serial line at 9600 Baud.

The program, written in ASSEMBLY language, resident on EPROM, allows the user to work with the remote computer in transparent mode, or, by appropriate command, to transfer a data file from the MCA to the computer (using a single RS-232 C line).

Moreover, the MCA spectrum can be transferred to a graphic printer in order to have a very low-cost hard copy.

A circular buffer built in, reduces the number of interrupt requestes to the VAX when using the printer.

MECHANICAL WORKSHOP

L. Donà, A. Dainese, G. Donà, L. Furiato, S. Marigo
E. Morandin, M. Negrato, R. Preciso

I.N.F.N., Laboratori Nazionali di Legnaro, Legnaro (Italy)

The construction and assembling of a sliding seal scattering chamber (60 cm diameter) was completed during 1984. The chamber has been successively installed on the -20 beam line of the Tandem accelerator, where it has been since then extensively used for experiments. The chamber allows rotations of up to 90° without breaking (routinely better than 10^{-6} mbar).

Another scattering chamber to be used for experiments on trace element analysis is being constructed, aswwell as the mechanical components of a pulsed beam monitoring system to be installed at the Tandem. Completion of these two items is foreseen within the first two months of 1985.

Meanwhile, two more works are in progress:

1) an electrostatic deflector for ultra sensitive Tandem mass spectrometry;

2) a large turntable (∿6 m diameter) for measurements with heavy ion gas detectors.

These set-ups are going to be completed within 1985.

The workshops, moreover, insured routine and emergence assistance to the users of the three accelerators of the laboratory.

TARGET LABORATORY

G. Manente, R. Pengo

I.N.F.N., Laboratori Nazionali di Legnaro, Legnaro (Italy)

Thin films have been prepared to be used as targets for the three accelerators installed at the L.N.L. The methods used include the Electron Gun (E.G.), Joule effect, pack rolling. Carbon foils of ~5 μg/cm^2 were also prepared by E.G. for use as strippers in the XTU Tandem. A "glow discharge" system has been installed to clean by micro-sputtering the substrates before the evaporation takes place. This device has found an useful application in preparing the glass substrates in Solid State Physics experiments[1]. It has been built an hydrogen reduction system for oxides which uses a Palladium cell to purify the gas flowing. The device is now operational. Targets of Sn were also prepared by electrodeposition for which invaluable was the help of T. Morgan, guest of the target laboratory last November. Other targets (e.g. ^{48}Ca) were prepared by rolling in a glove--box at the Technologische Labor Garching facility. A similar device is under construction at our Laboratory.

Special topics:

(a) Calibration films for PIXE analysis

A special effort was done in order to prepare samples of most of the natural elements for PIXE analysis of aerosols. The accuracy of the thickness allowed the measurements of very small amount of trace element[2].

(b) Preparation of very thin gold layer for use as electron emitters of Micro-Channel Plates

A special device[3] has been built at our Laboratory in order to prepare thin (~80Å) gold layers on FORMVAR (5-20 μg/cm^2). Those composite films, with high mechanical resistance, have been used successfully in conjuction with a MCP in a time-of--flight telescope for heavy ions.

References

(1) G. Battaglin, private communication.

(2) P. Mittner et al., to be published.

(3) R. Pengo et al., Nucl. Instr. and Methods, in press.

COMPUTING CENTRE AND ON-LINE DATA ACQUISITION SYSTEMS

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The computing center group supports the maintenance and the development of software for the computing center's VAX and for the dedicated on-line data acquisition computers. All these computers are linked together via a Dec-Net network. A high speed local network (based on Ethernet) is being installed improving the data exchange between the acquisition systems and the computing center. In addition, the lab's computers are inserted into the national computer network of the "Istituto Nazionale di Fisica Nucleare" (INFNET). Using the INFNET facilities the computer's lab is connected to almost all of the lab users and to other national and international computer networks (e.g. CERN's network, EARN/BITNET, etc.).

Computing Center

The computing center is provided with a VAX 11/780 with 2.25 Mbyte of central memory, two 67 Mbyte removable disks, a 512 Mbyte fixed disk, a 6250/1600 bpi tape drive unit and with two 1600/800 bpi units. The printer outputs are produced by means of a 600 lpm line printer. Several graphics devices are available: a pen plotter, an electrostatic printer/plotter (200 dot/inch), two color terminals and several graphics terminal. The activities of the center range from off-line data analysis to theoretical and simulation calculations. Software facilities are provided for microprocessor development (cross compiler, linkers, etc.), for text formatting (using as output the 200 dot/inch electrostatic plotter), for graphics development, etc. Automatic procedures for accounting give weekly control reports on the computer resource distribution. During this year some programs for data analysis and theoretical calculations were modified according to the local facilities.

Status of the on-line data acquisition systems at the TANDEM LABORATORY

During this year the systems[1)] worked satisfactorily. The upgrades were concerned mainly with the software:

- Remote task line loading from VAX, via DEC-NET, for no-time critical tasks. The memory resident system (based on RSX11S) can load the tasks from the VAX disks (quite similar to an on-line disk).

- Extension of the KINETICS CAMAC library to the interrupt handler coming from LAM.
- A faster on-line procedure to set up the experimental configuration.
- New commands to use a charge integrator connected to a CAMAC scaler.
- Fixing of a few "bugs" that were in the system.

The improved CN system will be brought as soon as possible to the TANDEM acquisition systems.

On-line data acquisition system at the CN LABORATORY

A new on-line data acquisition system is being installed at the CN lab. The system consists:

- one PDP 11/24 with 512 kbyte of central memory;
- one magnetic tape drive (800/1600 bpi);
- two 10 Mbyte removable disks;
- a home-made part providing the parallel acquisition of 8 different event types, each of them may have up to 16 parameters[4];
- a pen plotter;
- an alphanumeric terminal:
- a high resolution graphics display (Tek 4010);
- a CAMAC crate directly connected to the UNIBUS via a 3912 KINETICS crate controller;
- a DUAL PORT CAMAC MEMORY to build the singles and projections spectra[2];
- a CAMAC DMI CONTROL to control the DUAL PORTO CAMAC MEMORY (modified version of [3]).

Special care has been devoted to plan the system (both hardware and software) as an improvement of the TANDEM's present acquisition system[1]. In a short time the system will be upgraded with microprocessor-based CAMAC modules for on-line data processing[5] and with a CAMAC CRT controller described in [6].

References

(1) G. Bassato, M. Morando, G. Prete, Annual Report LNL (1983) 89.

(2) A. Fois, "A dual port CAMAC memory", this report.

(3) A. Cristofoli, G. Prete, Annual Report LNL (1983) 86.

(4) G. Bassato et al., Annual Report LNL (1980) 108.

(5) G. Bassato, "A CRT controller for a real-time display in the data acquisition system at LNL", this report.

(6) G. Bassato, Annual Report LNL (1983) 81.

\- ACCELERATORS -

ACCELERATORS MAINTENANCE AND DEVELOPMENTS

F. Cervellera, G. Bezzon, B. Azzara, G. Battistello, G. Battistello, S. Benvegnù, L. Bertazzo, G. Binelle, R. Bortolami, I. Carraro, L. Costa, G. Egeni, G. Gonella, I. Motti, G. Muraro, R. Pagnin, A. Rinaldi, F. Scarpa, V. Rudello, L. Ziomi

During 1984 the Tandem XTU operated for long time without noticeable problems.

Until July only normal maintenances took place. The Laddertron chain mounted in 1983 worked very satisfactorily even if many adjustments of mechanical tension are required. The major problem concerning Laddertron is so far the life of pulley bearings and we spent some time in 1984 to replace them.

In August, September and October the machine stopped and a long, not ordinary, maintenance took place essentially for monitoring the security valves at the ends of accelerating tubes to prevent SF_6 leakage in case of vacuum breakage in the beam path inside the machine. In the same time a new resistor system for the voltage devider has been mounted in column sections n° 4 and 5 as indicated in a previous report. The machine came back to experiments in last November after testing the LCE-710 Li-He source. The results of the test are good enough and make it possible normal running with this type of source.

In order to ensure more reliability a new analysing magnet has been designed and ordered for the Tandem injector. The aim is to have two sources mounted in two separate inputs and so to save time to switch from one another (sputtering and Li charge exchange sources, for instance).

The problem of replacing the actual (T2") tubes with new ones (88") has been extensively studied. The final decision is to make the replacement in the first part of 1986. The tubes (7 of 88" length and 1 of 96" length) are now in stock at L.N.L. They arrived here at the end of 1984. A prototype of new connection dead sections is in advanced work in the mechanical shop of L.N.L.

Concerning the other accelerators we remember that many troubles arose at the CN in order to reach the maximum voltage (7 MV) as previously done. At the end of 1984 the goal was reached and now the machine is ready for experiments at the maximum terminal voltage.

The small accelerator AN-2000 worked satisfactorily and only ordinary scheduled maintenance was necessary.

We must remember also the conclusion of mounting the 150 kV accelerator designed essentially for ion implantation. Tests of current extraction are now running.

XTU TANDEM ACCELERATOR LABORATORY

R.A. Ricci

I.N.F.N., Laboratori Nazionali di Legnaro, Legnaro (Italy) and Department of Physics, University of Padova (Italy)

The Laboratory of the XTU Tandem accelerator has been provided in 1984 with the necessary conditions and equipment for the scientific program, specified elsewhere.

Here we report the utilization and the relevant performances of the machine and the experimental areas.

1) *Accelerator utilization*

Table I shows the distribution of the machine-time in 1984 (from February 3rd to December 23rd).

TABLE I

	hours	% of real time
- Beam for experiment	4.200	65
- Beams alignment and tests of experimental apparatus	164	2
- Conditioning	1.260	19
- Breaking and maintenance	847	14
Total	6.471	100

2) *Ion beams*

TABLE II

p	6%	^{18}O	3%
d	4	^{28} ^{30}Si	16
^{7}Li	2	^{32}S	45
Be	4	^{35}Cl	4
C	4	^{58}Ni	5
^{16}O	7	^{79}Br	1

3) *Experimental programs*

- Heavy-ion reactions and dissipative phenomena 52%
- γ-spectrometry with heavy ions 23%
- Nuclear spectroscopy and transfer reactions with light ions 15%
- Interdisciplinary science (mass spectrometry, biophysics, neutron dosimetry) 10%

4) *Machine performances*

Fig. 1 shows terminal voltage performances in 1984.
Concerning the injection system and ion sources, the standard sputter 834 source has been extensively used, whereas the duoplasmatron charge-exchange LCE/710 source has been installed and tested with a maximum of 20 hours running time.
The performances of that source are guaranteed with the following beams:

^{4}He	1	μA
^{3}He (gas)	1	μA
^{6}Li	40	nA
^{7}Li	500	nA.

The time required to install the source is 48 hours and 30 supplementary hours are needed for replacing the Litium charge.
Concerning the high intensity sputter source HICONEX 860, the preliminary tests have been started.

5) *The beam pulsing system*

The beam pulsing system installed at the XTU Tandem Laboratory consists of a low-energy chopper, a buncher, a post--chopper, and associated electronics (fig. 2). Before injection into the accelerator, the beam is chopped to 40 ns pulses (repetition rate 2.5 MHz average current ∿10% D.C. beam) and then bunched to achieve pulse widths in the nanosecond range. The buncher acts as a velocity modulator of the chopper beam by a double compression gap working at a master frequency of 5 MHz.
After acceleration the beam is transmitted through the post--chopper which compensates for drifts in beam transit time through the accelerator. The time structure of pulsed beams has been measured by detecting either elastically scattered ions or prompt γ-rays; the results reported in Table III refer to the overall time spread, including the detector and associated electronics timing uncertainties.

TABLE III

Time resolutions obtained with the XTU pulsing system for selected ion beams. The measured FWHM time spread includes the time uncertainty of the detection system: (1) surface-barrier detector, (2) NE 104 scintillator.

Beam	E (MeV)	FWHM (ns)
P	26.	0.7 (1)
^{3}He	25.	0.8 (2)
^{12}C	77.	1.1 (1)
^{32}S	130	1.2 (1)

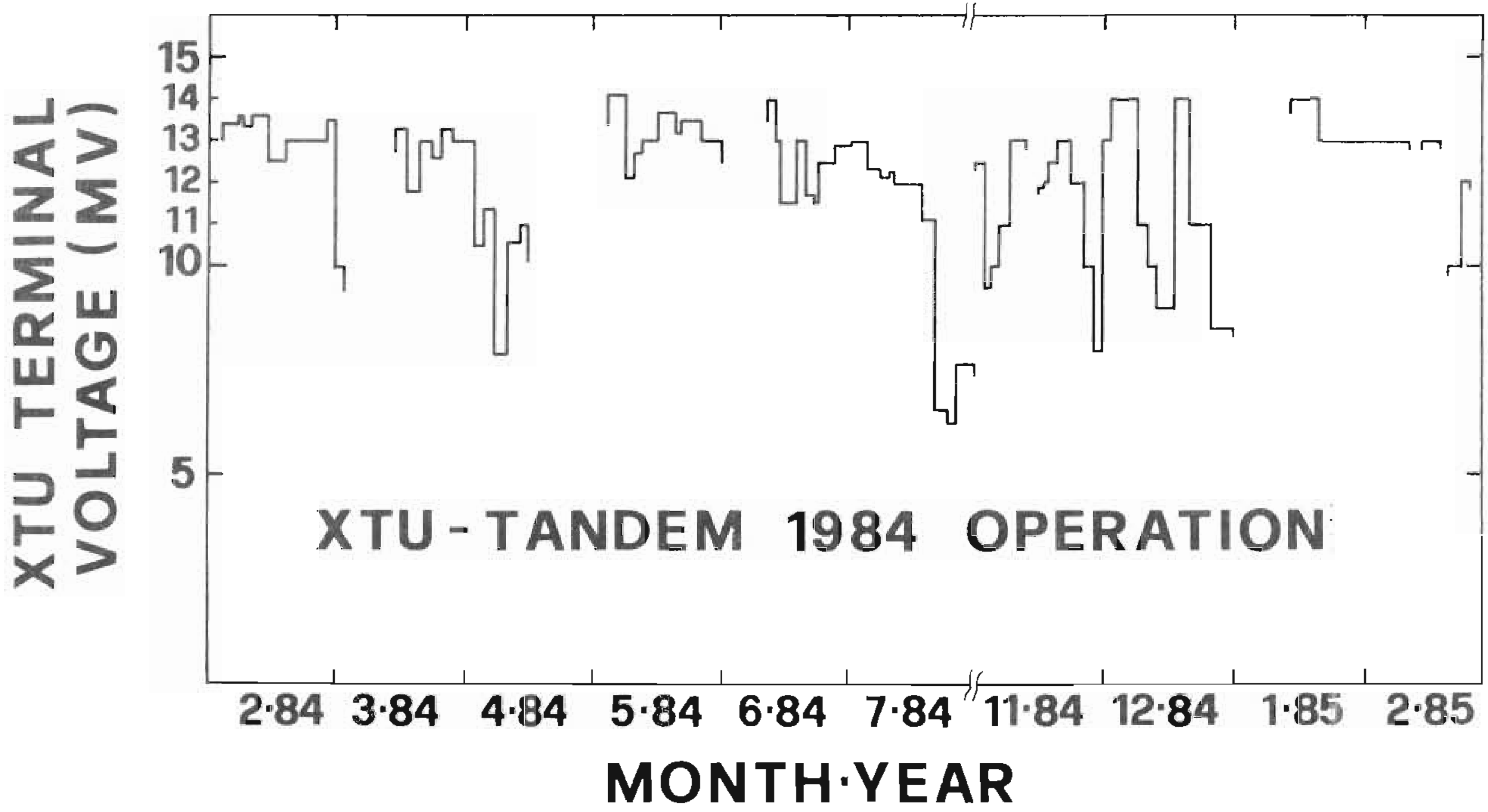
6) *Experimental rooms and beam lines*

The following facilities have been provided:

a) a "sliding seal" chamber at the second measurement point of the 20° beam line in the west area;

b) all beam lines have been provided with the slits and Faraday cups;

c) the project for providing the 40° beam line in the west area with a supplementary switching magnet needed for the installation of the heavy ion spectrometer has been completed.


XTU TERMINAL VOLTAGE (MV)
15
14
13
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XTU - TANDEM 1984 OPERATION
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7·84
11·84
12·84
1·85
2·85
MONTH·YEAR

Fig. 1

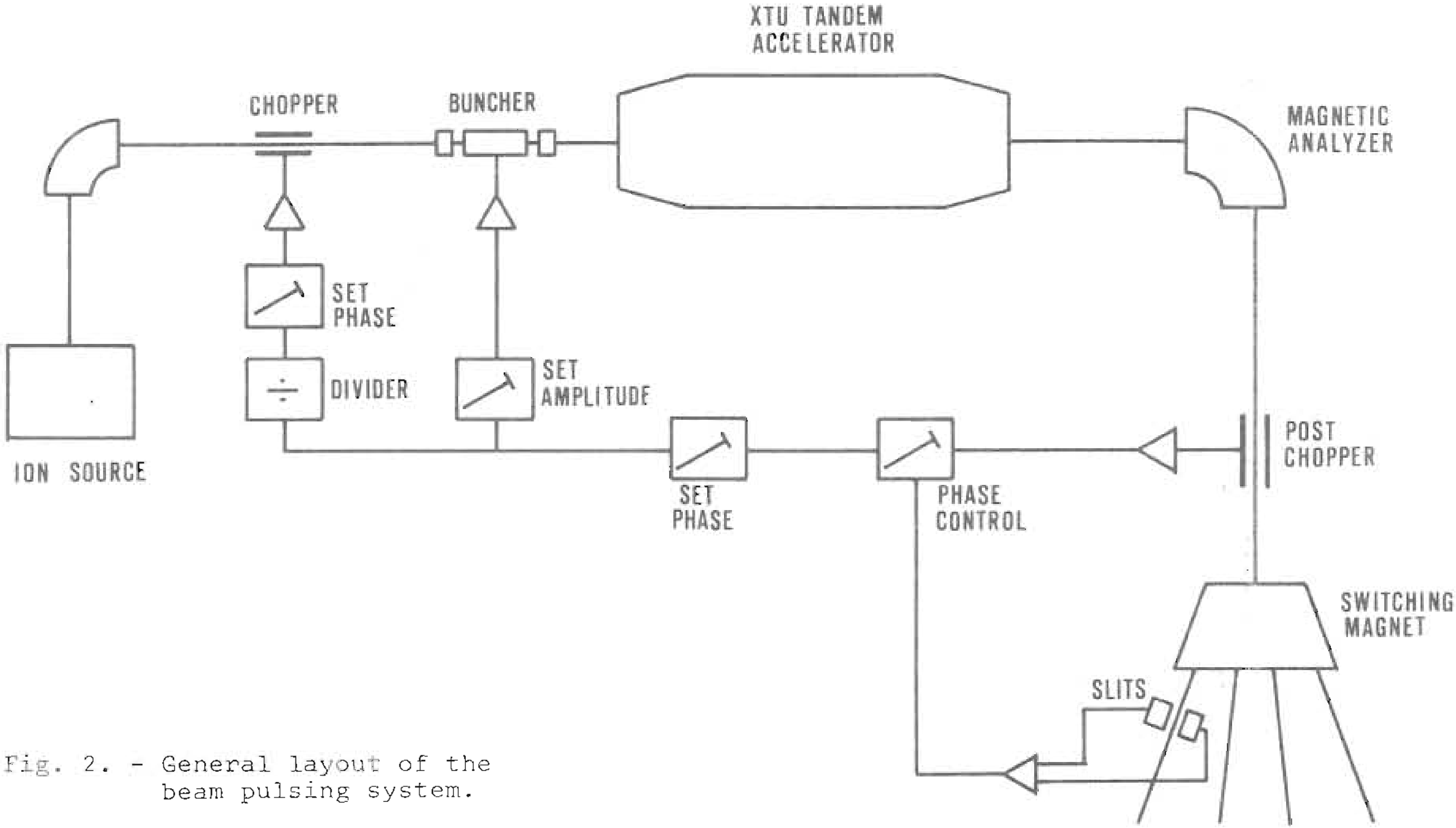

Fig. 2. - General layout of the
beam pulsing system.

2 MV ACCELERATOR LABORATORY

P. Mazzoldi

Department of Physics, University of Padova (Italy) and I.N.F.N., Laboratori Nazionali di Legnaro, Legnaro (Italy)

Throughout 1984 the Van de Graaff 2 MV accelerator has been operated 2500 hours.

1984

Beam time	2550 h
Conditioning	30 h
Maintenance	320 h
Failure	100 h.

The AN-2000 machine produces proton, deuteron, $^{4}He^{+}$, $^{14}N^{+}$, $^{40}Ar^{+}$ beams with a maximum current density of some μA.

The ion implanter produces ion beam from gaseous elements, as H, ^{10}B, ^{11}B, ^{40}Ar, ^{14}N, ^{84}Kr, with current of 50-100 μA.

In the laboratory there are six experiment stations for the research groups.

The research groups working in the 2 MV Laboratory are the following: Sezione I.N.F.N. - Napoli (X-ray excitation cross section measurements), Department of Physics - Modena (pollution analysis by using proton induced X-ray emission PIXE and solid state physics studies with Rutherford backscattering techniques, RBS), Department of Physics - Padova (pollution analysis by using PIXE and solid state physics phenomena with RBS and nuclear reactions - NRA), La.M.El. - C.N.R. - Bologna (solid state physics with RBS and NRA), Department of Electronics - Padova (waveguides characterization by using RBS and NRA), Legnaro Laboratory (biological samples analysis by using PIXE), Orsay Laboratories (solid state physics by using NRA).

Moreover, students who attend the last courses of the Physics Faculty perform some basic nuclear physics experiments in this Laboratory.

7 MV ACCELERATOR LABORATORY

G. Moschini

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During 1984 the Laboratory experimental capabilities have been strengthened by means of the following facilities:

- an online data acquisition system based on a Digital PDP 11/24, which will be operating at the beginning of the next year;
- a new beam line for radiobiological applications research.

Moreover a new safety radiation monitoring system has been setted up. The operation time of the 7 MV Accelerator during the same period has been divided as follows:

1- research: 1862 hr.
2- maintenance: 1872 hr.

Research hours have mainly been utilized for fundamental studies (1134), while the remaining ones (728) have been dedicated to applied research.

Few more hours (94) have been employed for students training and for beam alignements.

- SEMINARS AND MEETINGS -

SEMINARS 1984

January 19, 1984	R.A. Broglia (*Niels Bohr Institute, Copenhagen*) "SEMICLASSICAL DESCRIPTION OF PAIRING CORRELATIONS IN NUCLEI"
February 3, 1984	Z. Sujkowski (*Institute for Nuclear Studies, Swierk, Poland*) "IDENTIFICATION OF THE ATOMIC NUMBER OF HEAVY RESIDUES OF NUCLEAR REACTIONS BY THE PARTICLE -KX- RAY COINCIDENCE METHOD"
February 10, 1984	A. Del Guerra (*Department of Physics, University of Pisa*) "HISPET: TOMOGRAFO A POSITRONI DI ALTA RISOLUZIONE"
February 22, 1984	C. Birattari (*Department of Physics, University of Milano*) "PROBLEMATICHE RELATIVE ALLA PRODUZIONE DI RADIOISOTOPI DI USO BIOMEDICO"
March 28, 1984	D.M. Brink (*University of Oxford*) "QUASI ELASTIC HEAVY-ION REACTIONS"
April 4, 1984	S. Skorka (*Sektion Physik, University of Munich*) "INVESTIGATION UNBOUND HIGH SPIN STATES IN ^{27}Al. (ARE THEY SUPERDEFORMED?)"
April 11, 1984	S. Tazzari (*I.N.F.N., Laboratori Nazionali di Frascati*) "RICERCHE SUGLI ACCELERATORI PRESSO I LABORATORI NAZIONALI DI FRASCATI"

April 16, 1984

G. Vitale (*LASI Elettronica, Milano*)
F. Montanari (*National Semiconductors, Milano*)
P. Pepori (*National Semiconductors, Milano*)
" - FAMIGLIA NS 16000 -
a) Generalità e architettura
b) Programmazione del microprocessore a 32 bit NS 16000
c) Software e strumenti di sviluppo"

April 17, 1984

D. Elmore (*University of Rochester, New York*)
"THE TANDEM ACCELERATOR MASS SPECTROMETRY PROGRAM AT ROCHESTER"

May 2, 1984

G. Perlini (*CCR, Ispra*)
"SPETTROMETRIA NEUTRONICA AD ENERGIE MINORI DEL MeV CON PICCOLI SPETTROMETRI"

May 3, 1984

D. Dumitrescu (*Central Institute of Physics, Bucharest*)
"FERMI-LIQUID MODEL OF ALPHA-DECAY"

May 9, 1984

C. Manfredotti (*Institute of Physics, University of Torino*)
"RIVELATORI A SEMICONDUTTORE: PROBLEMI E PROSPETTIVE"

May 16, 1984

M. Bonardi (*Department of Physics, University of Milano, Cyclotron Laboratory*)
"ASPETTI RADIOCHIMICI CONNESSI CON LA PRODUZIONE DI RADIONUCLIDI MEDIANTE ACCELERATORI"

May 23, 1984

U. Kaup (*Institute of Nuclear Physics, University of Cologne, West Germany*)
"EFFECT OF THE PAULI PRINCIPLE ON COLLECTIVE STATES IN THE INTERACTING BOSON MODEL"

June 1, 1984	F. Catara *(Institute of Physics, University of Catania and Heidelberg University)* "DISTORSIONI DINAMICHE NELLE COLLISIONI FRA IONI PESANTI"
June 8, 1984	V. Benzi *(Centro Ricerche Energia "E. Clementel" - ENEA)* "SPETTRO ENERGETICO E RESA DELLA REAZIONE (α,n) IN COMBUSTIBILI NUCLEARI"
June 14, 1984	R. Santo *(University of Münster)* "REACTION MECHANISMS AT MEDIUM ENERGIES (20÷100 MeV/nucleon) RESULTS FROM CERN"
June 20, 1984	J.J. Broerse *(Medical Biolgocial Laboratory - TNO - Rijswik, The Netherlands)* "NEUTRON THERAPY: RESULTS AND PERSPECTIVES"
July 18, 1984	P. Doleschall *(Central Research Institute for Physics, Budapest)* "TRITON PROBLEM"
October 9, 1984	N. Takahashi *(University of Osaka, Japan)* "THE RESEARCH CENTER FOR NUCLEAR PHYSICS AT OSAKA. STUDY OF UNSTABLE NUCLEI BY H.I. REACTION"
October 24, 1984	G. Brautti *(Department of Physics, University of Bari)* "ESPERIMENTI POSSIBILI DI FISICA ATOMICA, NUCLEARE E DI ASTROFISICA CON UN ANELLO DI ACCUMULAZIONE PER IONI PESANTI"

November 7, 1984	H. Menzel (*Institute für Biophysik der Universität des Saarlandes*) "APPLICATIONS OF MICRODOSIMETRIC TECHNIQUES IN RADIATION BIOLOGY AND RADIATION PHYSICS"
November 9, 1984	D.A. Bromley (*Physics Department, Yale University, U.S.A.*) "RECENT ASPECTS OF HEAVY ION PHYSICS"
November 14, 1984	M. Quintiliani (*Istituto Tecnologie Biomediche del C.N.R., Roma*) "LA RADIOBIOLOGIA DEGLI ANNI '80"
November 15, 1984	P. Kleinheinz (*Institut für Kernphysik der KFA, Jülich*) "SINGLE AND DOUBLE OCTUPOLE EXCITATIONS"
November 28, 1984	T. Morgan (*Schuster Laboratory, Department of Physics, Manchester University*) "HISTORY AND DEVELOPMENT OF TARGET MAKING AT MANCHESTER AND DARESBURY LABORATORIES TO MODERN DAY STANDARD"
November 30, 1984	C.H. Dasso (*NORDITA, Copenhagen*) "SUB-BARRIER FUSION REACTIONS"
November 30, 1984	G. Nebbia (*Cyclotron Institute, Texas A&M University*) "REAZIONI DI FUSIONE INCOMPLETA INDOTTE DA IONI PESANTI AD ENERGIE INTERMEDIE"
December 5, 1984	E. Festa (*Orsay Laboratories*) "STATISTICAL MEASUREMENTS OF TIME-OF-FLIGHT IN MASS SPECTROMETRY USING INDUCED DESORPTION"

December 19, 1984 R. Rohe (*I.N.F.N., Laboratori Nazionali di Legnaro*)
"SPIN DISTRIBUTIONS ASSOCIATED WITH SUB-
-BARRIER FUSION OF HEAVY IONS"

MEETINGS 1984

"*Three-day in depth review on the nuclear accelerator impact in the interdisciplinary field*", May 30th - June 1rst, 1984

"*ESONE CAD Seminar, General Assembly and CAD Exhibition*", September 26-28, 1984

- LIST OF PUBLICATIONS -

C. Signorini, G. Bezzon, F. Cervellera, P. Spolaore, R.A. Ricci:
"Acceptance tests of the Legnaro XTU Tandem"
Nucl. Instr. and Meth. 220 (1984) 30.

P. Spolaore, J.D. Larson, C. Signorini
"A wide acceptance recoil mass spectrometer for the LNL XTU Tandem accelerator"
Il Nuovo Cimento 81A (1984) 351.

A. Geuer-Richter (a cura di R. Pengo):
"Preparazione di films sottili per esperimenti di fisica nucleare con acceleratori di particelle"
Report INFN/TC-84/1.

A.M. Stefanini, G. Fortuna; A. Tivelli, W. Meczynski, R. Pengo, S.J. Skorka, S. Beghini, C. Signorini, S. Lunardi, M. Morando:
"Fusion below the barrier of $^{28-30}$Si and ^{37}Cl with $^{58-62-64}$Ni"
Contr. Int. Symp. on Heavy-Ion Fusion Reaction, Tsukuba (Japan), Sept. 3-5, 1984 (in press).

C. Rossi Alvarez, G. Bezzon, P. Blasi, J.C. Drau, J.C. Petit, G. Della Mea:
"Leaching of glasses studied by using nuclear techniques"
Contr. Int. Symp. on Three-Day In-Depth Review on the Nuclear Accelerator Impact in the Interdisciplinary Field, LNL May 30 June 1, 1984 (in press).

G. Della Mea, J.C. Drau, J.C. Petit, G. Bezzon, C. Rossi Alvarez:
"New data on ion-induced modifications of acqueous disolution of silicates"
Mat. Res. Soc. Symp. Proc. 26 (1984).

C. Tuniz, B.M. Stievano, M. Lombardi, P. Spolaore, G. Moschini, R.A. Ricci, T.H. Kruse, G.F. Herzog:
"High-energy mass spectrometry at the XTU Tandem accelerator of the Laboratori Nazionali di Legnaro"
Nuovo Cimento, in press.

M. Gentili, I. Massa, G. Vannini, P. Boccaccio, F. Reffo, L. Vannucci, R.A. Ricci, I. Iori:
"Intermediate mechanisms in the fussion-like fragmentation"
Fizika 16 (1984) 57.

M. Gentili, I. Massa, G. Vannini, P. Boccaccio, F. Reffo, L. Vannucci, R.A. Ricci, I. Iori:
"Dynamical model analysis of intermediate mechanism in ^{32}S-induced reactions"
Lett. Nuovo Cimento 40 (1984) 505.

R. Pengo, P. Boccaccio, G. Manente, L. Vannucci, I. Massa, G. Vannini:
"The preparation of thin films for use as electron emitters for micro-channel plates"
Inviato a Nucl. Instr. and Meth.

S. Lunardi, S. Beghini, M. Morando, C. Signorini, G. Fortuna, W. Meczysnki, A.M. Stefanini:
"Study of neutron-poor nuclei in the Sm-Gd region"
Proc. Int. Symp. on In-beam Nuclear Spectroscopy, Debrecen (Ungheria), 14-18 Maggio 1984, Atomki Report A/2 (1984), Huissn 0231-3693.

A.M. Stefanini, G. Fortuna, A. Tivelli, W. Meczynski, G. Montagnoli, S. Beghini, C. Signorini, S. Lunardi, M. Morando:
"Sub-barrier fusion of the systems $^{28-30}Si+^{58-62-64}Ni$"
Proc. Int. Conf. on Fusion Reactions below the Coulomb Barrier, MIT (Mass., USA), 13-15 Giugno 1984, in corso di pubblicazione su Lecture Notes in Physics.

G. Fortuna, C. Signorini, A.M. Stefanini, Y. Nagashima, S. Beghini, S. Lunardi, W. Meczynski, M. Morando:
"An electrostatic beam deflector for heavy-ion fusion evaporation studies at ODEG"
Contr. Int. Symp. on Heavy-Ion Fusion Reaction (Tsukuba, Giappone) Sett. 1984, in corso di pubblicazione.

C. Signorini, G. Fortuna, A.M. Stefanini, S. Beghini:
"Sub-barrier fusion reactions and related experimental techniques"
Invited talk at the 1984 INS-RIKEN Int. Symp. on Heavy-Ion Physics (Tokjo, Giappone), Agosto 1984, in corso di pubblicazione.

A.M. Stefanini, G. Fortuna, A. Tivelli, W. Meczynski, S. Beghini, C. Signorini, S. Lunardi, M. Morando:
"Sub-barrier fusione of $^{28-30}Si$ with $^{58-62-64}Ni$"
Phys. Rev. C30 (1984) 2088.

F. Geotti-Bianchini, P. Polato, S. Lo Russo, P. Mazzoldi:
"Antireflective effects on a soda-lime glass induced by Ar^+ implantation".
Journ. Americ. Ceramic Society 67, n.1, 39 (1984).

A. Manara, F. Lanza, G. Della Mea, C. Rossi Alvarez, G. Salvagno:
"Influence of redox condition in iron, silicon and hydrogen contents of leached glass surface"
Scientific Basis for Nuclear Waste Menagement .
Ed. G.L. Mc. Vay North Holland, New York (USA).

J.C. Petit, Y. Langevin, J.C. Drau, G. Della Mea:
"Etude par implantation ionique des effects d'irradiation sur la dissolution des verres et des mineraux silicates"
Annales de Chimie 9 (1984) 543.

A. Bertin, R.A. Ricci, A. Vitale:
"Fifty years of weak interaction physics"
Italian Physical Society, Bologna 1984.

S. Focardi, R.A. Ricci:
"The beta-decay and the fundamental properties of weak interactions"
Italian Physical Society: Fifty Years of weak interaction physics", edited by A. Bertin, R.A. Ricci, A. Vitale.

L. Moretto, R.A. Ricci:
"Nuclear structure and heavy ion dynamics"
Proc. Int. School of Physics, Varenna, 1982
North Holland 1984.

P. Boccaccio, R.A. Ricci:
"Intermediate mechanisms in the fission-like fragmentation of 100 nuclear systems"
Proceedings 5th Int. Conf. on Nuclear Phys. HVAR, Croatia, 24-29 Settembre 1984. In corso di pubblicazione.

M. Gentili, I. Massa, G. Vannini, P. Boccaccio, F. Reffo, R.A. Ricci, L. Vannucci, I. Iori;
"Generalized extra-push model calculations and intermediate mechanisms for low mass heavy-ion reactions"
Lettere al Nuovo Cimento, vol. 39 n. 10, Marzo 1984.

F. Gramenga, M. Pavanti, G. Prete, R.A. Ricci, G. Viesti, I. Iori, Li-Zu-Yu, A. Moroni, G. d'Erasmo, L. Fiore, A. Pantaleo:
"The $^{100}Mo+^{32}S$ reaction at $E_{lab}=150$ MeV"
Il Nuovo Cimento, vol. 79 A, n. 4, Febbraio 1984.

R.A. Ricci:
"First experimental results at the XTU Tandem of the Laboratori Nazionali di Legnaro"
Il Nuovo Cimento, vol. 81A n. 1, Maggio 1984.

A. Moroni, I. Iori, G. Prete, G. Viesti, F. Gramegna:
"Nitrogen isotopes identification by Bragg curve spectroscopy"
Lettere al Nuovo Cimento 40, 1984, 321.

G. Prete, G. Viesti, A. Moroni:
"Developments of heavy-ion gas detectors at L.N.L."
Il Nuovo Cimento 81A, 1984, 208.

A. Moroni, I. Iori, Li-Zu-Yu, G. Prete, G. Viesti, F. Gramegna, A. Dainelli:
"Position sensitive and Bragg curve spectroscopy dedector system"
Nucl. Instr. and Meth. 225, 1984, 57.

G. Prete, G. Viesti:
"Discrimination capability of avalanche counters"
Nucl. Instr. and Meth. in press.

A. Moroni, I. Iori, Li-Zu-Yu, G. Prete, G. Viesti, F. Gramegna:
"Charge and mass identification by Bragg curve spectroscopy"
XXII Int. Winter Meeting on Nuclear Physics, Bormio 1984, p. 444.

F. Gramegna, G. Prete, R.A. Ricci, G. Viesti, A. Moroni, I. Iori, G. d'Erasmo, L. Fiore, A. Pantaleo, P. Blasi, G. Lucarelli:
"^{32}S on ^{58}Ni reaction at E_{lab}=143 MeV: spin and spin alignment of the target-like products"
1984 INS-RIKEN Int. Symp. on Heavy-Ion Physics, Riken 1984, Contributed Papers, p. 71.

C. Cohen, J. Siejka, M. Berti, A.V. Drigo, G.G. Bentini, D. Pribat, E. Jannitti:
"Pulsed laser irradiation of GaaS under oxygen and silane atmosphere: incorporation, losses, influence of native oxides"
J. Appl. Phys. 55, 4081, 1984.

M. Berti, A.V. Drigo, C. Cohen, J. Siejka, G.G. Bentini, R. Nipoti, S. Guerri:
"Titanium silicide formation: effect of oxygen distributions in the metal films"
J. Appl. Phys. 55, 3358, 1984.

J.C. Boulliard, C. Cohen, J.L. Domange, A.V. Drigo, A. L'Hoir, J. Moulin, M. Sotto:
"Atomic displacements on stopped (16,1,1) copper structures: a channeling study"
Phys. Rev. B30, 2470-2486, 1984.

G.G. Bentini, M. Berti, C. Cohen, A.V. Drigo, S. Guerri, R. Nipoti, J. Siejka:
"Oxygen influence on titanium silicide formation"
Mat. Res. Soc. Symp. Boston 1983, vol. 25 p.137, 1984.
Elsevier Science Publishing Co., Inc.

G. Battaglin, R. Dal Maschio, G. Della Mea, G. De Marchi, V. Gottardi, M. Guglielmi, P. Mazzoldi, A. Paccagnella:
"Mechanical properties of ion implanted glasses"
Nucl. Instr. and Meth. B1, 253, 1984.

G. Battaglin, G. Della Mea, G. De Marchi, P. Mazzoldi, A. Miotello:
"Alkali migration in ion irradiated glasses"
Nucl. Instr. and Meth. B1, 511, 1984.

G. Battaglin, A. Carnera, G. Della Mea, L.F. Donà delle Rose, V.N. Kulkarni, P. Mazzoldi, A. Miotello, E. Jannitti, Animesh K. Jain, D.K. Sood, J. Chaumon:
"Pulsed laser treatment of la implanted Ni single crystals"
J. Appl. Phys. 55, 3773, 1984.

G. Battaglin, A. Carnera, G. Lodi, E. Giorgi, A. Daghetti, S. Trasatti
"Effect of the support on the surface properties of RuO_2 on silica glass"
J. Chem. Soc. Faraday Trans. I80, 913, 1984.

G. Battaglin, A. Carnera, L.F. Donà delle Rose, V.N. Kulkarni, P. Mazzoldi, E. D'Anna, G. Leggieri, A. Luches:
"Effects of pulsed elctron beam irradiation on Al single crystal with Pb overlayers"
in Energy Beam-Solid Interactions and Transient Thermal Processing, ed. by John C.C Fan and Noble M. Johnson, Mat. Res. Soc. Symp. Proc. vol. 23, Elsevier Science Publ. Co. Inc. New York, 1984, p. 769.

G. Battaglin, A. Carnera, G. Celotti, G. Della Mea, V.N. Kulkarni, S. Lo Russo, P. Mazzoldi:
"Ion beam mixing effects in Au-Fe and Pt-Fe thin bilayers"
in Ion Implantation and Ion Beam Processing of Materials, ed. by G.K. Hubler, C.R. Clayton, OW. Holland and C.W. White, Mat. Res. Soc. Symp. Proc. vol. 27, Elsevier Sci. Publ. Co. Inc. N.Y. 1984, p. 49.

G. Battaglin, G. Della Mea, G. De Marchi, P. Mazzoldi:
"Residence time before sodium migration in proton irradiated glasses"
Appl. Phys. Lett. 45, 736, 1984.

C. Canali, A. Carnera, G. Celotti, G. Della Mea, P. Mazzoldi:
"Planar waveguide formation process in $LiNbO_3$ by Ti ion-diffusion and H-Li ion exchange: a structural study"
in Material Research Society Symposia Proceeding 24, 1984, p. 459-465.

M.N.Armenise, C. Canali, M. De Sario, A. Carnera, P. Mazzoldi, G. Celotti:
"Ti diffusion process in $LiNbO_3$"
in New Directions in Guided Wave and Coherent Optics ed. by B.D. Ostrowsky e. E. Spitz, Martinus Nijhoff Publishers 1984, p. 623-637.

G. Cattapan, V. Vanzani:
"New developments in N-body scattering theory
Nuovo Cimento 81, 447, 1984.

G. Cattapan, V. Vanzani:
"Properties of chains of partitions and their applications to the N-body problem"
Nuovo Cimento, in press.

G. Cattapan, V. Vanzani:
"Properties of chains of partitions and their applications to the N-body problem"
Nuovo Cimento, in press.

G. Cattapan, V. Vanzani:
"New developments in N-body scattering theory III, Exact effective few-cluster reduction of N-body Faddeev-Yakubovskii-type equations"
Submitted to Nuovo Cimento.

G. Cattapan, V. Vanzani:
"Few-cluster reduction of multiparticle scattering equations and symmetrization procedures"
In Proc. Intern. Conf. on Clustering in Nuclei (Chester, 1984) p. 56.

G. Cattapan, V. Vanzani:
"Comparison between different reduction schemes of N--body scattering equations and particle identity"
In Proc. Europ. Conf. on Few Body problems in physics (Tblisi, 1984) p. 32.

F. Catara, A. Insolia, E. Maglione, A. Vitturi:
"Relation between pairing correlations and two-particle space correlations"
Phys. Rev. C29, 1984, 1091.

E. Maglione, A. Vitturi, F. Catara, A. Insolia:
"Description of odd-A deformed nuclei in the collective pair approximation"
Phys. Lett. 137B, 1984, 1.

F. Catara, A. Insolia, E. Maglione, A. Vitturi:
"Description of the even samarium isotopes in the collective pair approximation"
Phys. Rev. C29, 1984, 1916.

F. Catara, A. Insolia, E. Maglione, A. Vitturi, R.A. Broglia:
"Comparative study of the selectivity displayed by $(^{6}Li,d)$ and $(^{16}O,^{12}C)$ reactions"
Nucl. Phys. A424, 1984, 184.

E. Maglione, A. Vitturi:
"On the boson mapping of fermion collective pairs"
Nulc. Phys. A430, 1984, 158.

F. Catara, A. Insolia, E. Maglione, A. Vitturi:
"Two- and four-particel surface clusterization in deformed nuclei"
Phys. Lett. B, in press.

A. Vitturi, E. Maglione:
"Microscopic description of even and odd deformed nuclei in the collective pair approximation"
Proceedings of the workshop on Interacting boson-boson and boson-fermion systems, Ed. O. Schoelten, World Scientific Press, 1984, in press.

F. Catara, A. Insolia, E. Maglione, A. Vitturi:
"Two- and four-particle surface correlations in deformed nuclei"
Prcoeedings of the Int. Conf. on "Clustering Aspects of nuclear structure and nuclear reactions", Chester, 1984. Contributed papers.

P.F. Bortignon, R.A. Broglia, C.H. Dasso, C. Mahaux:
"Level dependence of the polarization correction to the hartree-fock single-particle energies in ^{208}Pb"
Phys. Lett. 140B, 163, 1984.

P.F. Bortignon, R.A. Broglia, G.F. Bertsch:
"Gamma decay of the giant quadrupole resonance in ^{208}Pb"
Phys. Lett. 148B, 1984, 20.

C. Mahaux, P.F. Bortignon, R.A. Broglia, C.H. Dasso:
"Dynamics of the shell model"
Phys. Reports, in press.

P.F. Bortignon:
"Nuclear dissipation and heavy-ion reactions"
Proceedings of the International Symposium on Nuclear Physics at Large Tandem Accelerators, Legnaro, 1983
A.M. Stefanini, R.A. Ricci eds., il Nuovo Cimento 81A 1984, p. 107.

P.F. Bortignon, R.A. Broglia, Xia-Ke-ding:
"Strength functions of giant vibrations"
Proceedings of the International Symposium on Highly Excited States and Nuclear Strucutre, Orsay, 1983, N. Marty, N. Van Giai eds., Journ. de Physique, C4, 1984, p. 209.

P.F. Bortignon:
"Strength distribution of giant resonances at high excitation energy"
In Proceedings of the workshop on "Perspectives on Nuclear Physics at Intermediate Energies, Trieste, 1983, S. Boffi, C. Ciofi degli Atti, M.M. Giannini, eds., p. 174, World Scientific Press, 1984.

P.F. Bortignon:
"Damping of collective modes"
Lectures given at the Winter College on Fundamental Nuclear Physics, Trieste, 1984, in press.

- ACCELERATOR USERS AND LABORATORIES PERSONNEL -

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RESEARCH STAFF

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