The Bucharest Tandem accelerator

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The Tandem van de Graaff accelerator

- High Voltage (USA) type, 1973 ;
- 9 MV on terminal;
- Beams: from protons to heavy ions (mass ~60) ;
- Fundamental (nuclear & atomic physics) and applicative research

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Large scale research

Advantages

- **Access to LSF's**
- **Address hot (top) physics issues**

Shortcomings

- **PAC, 'vogue', waiting time**
- **Students working on "data"**

Small scale research

Shortcomings

- **Small, old (often obsolete) facilities**
- **Address limited physics questions**

Advantages

- **Beam easily available**
- **Experiments : cases of special interest, (e.g., symmetries, 'niches' not well investigated); possible ideas of LSF investigations**
- **Educational value: students involved in all stages of an experiment**

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γ-ray spectroscopy

High-spin γ-ray spectroscopy with heavy-ion fusion-evaporation reactions;

Low spin γ-ray spectroscopy with (p,n γ) reactions

Beta decay studies ("special" cases)

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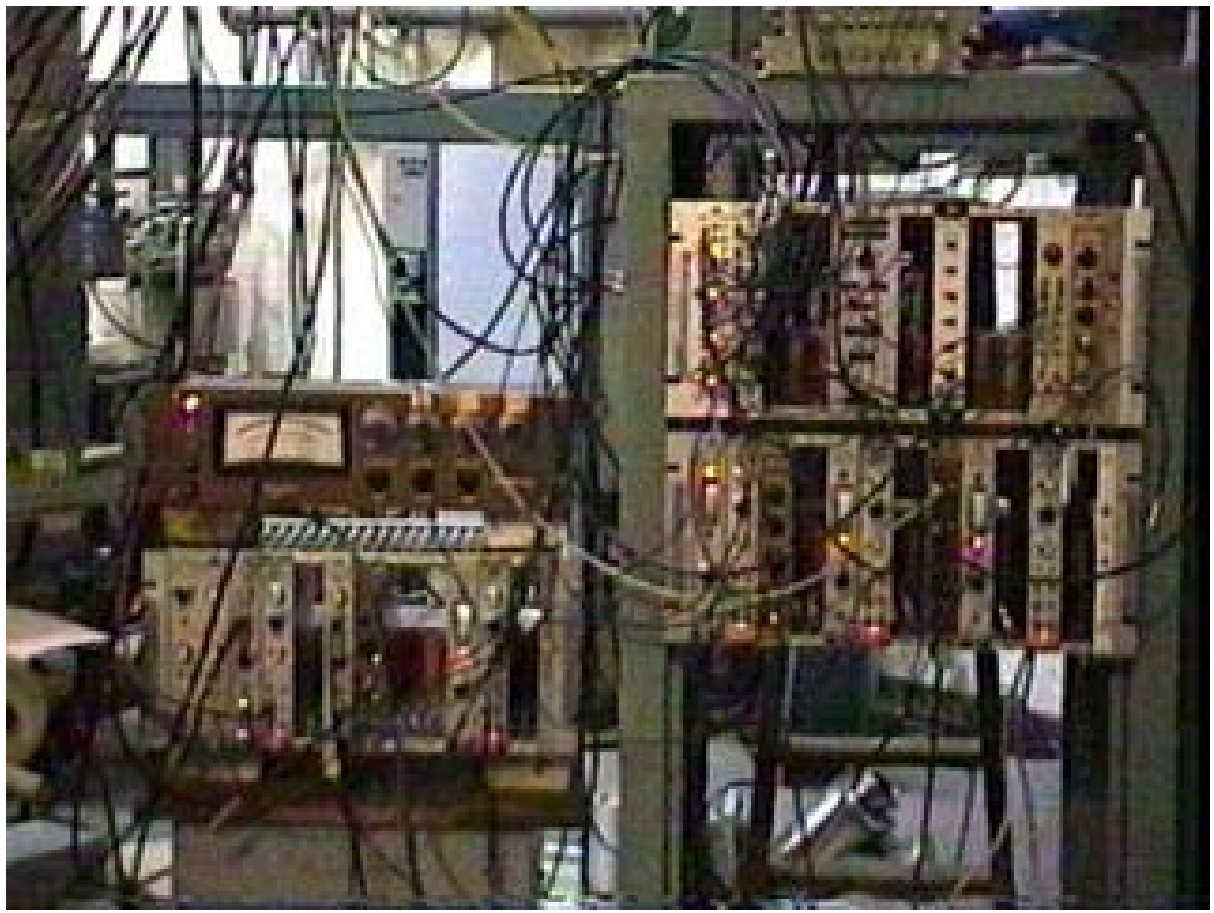
Multi-detector system for γ-ray spectroscopy

4(5) Ge HP detectors; 1(2) Si telescopes;
1- 5 neutron detectors (liquid scintillator)

Multi-detector system associated electronics



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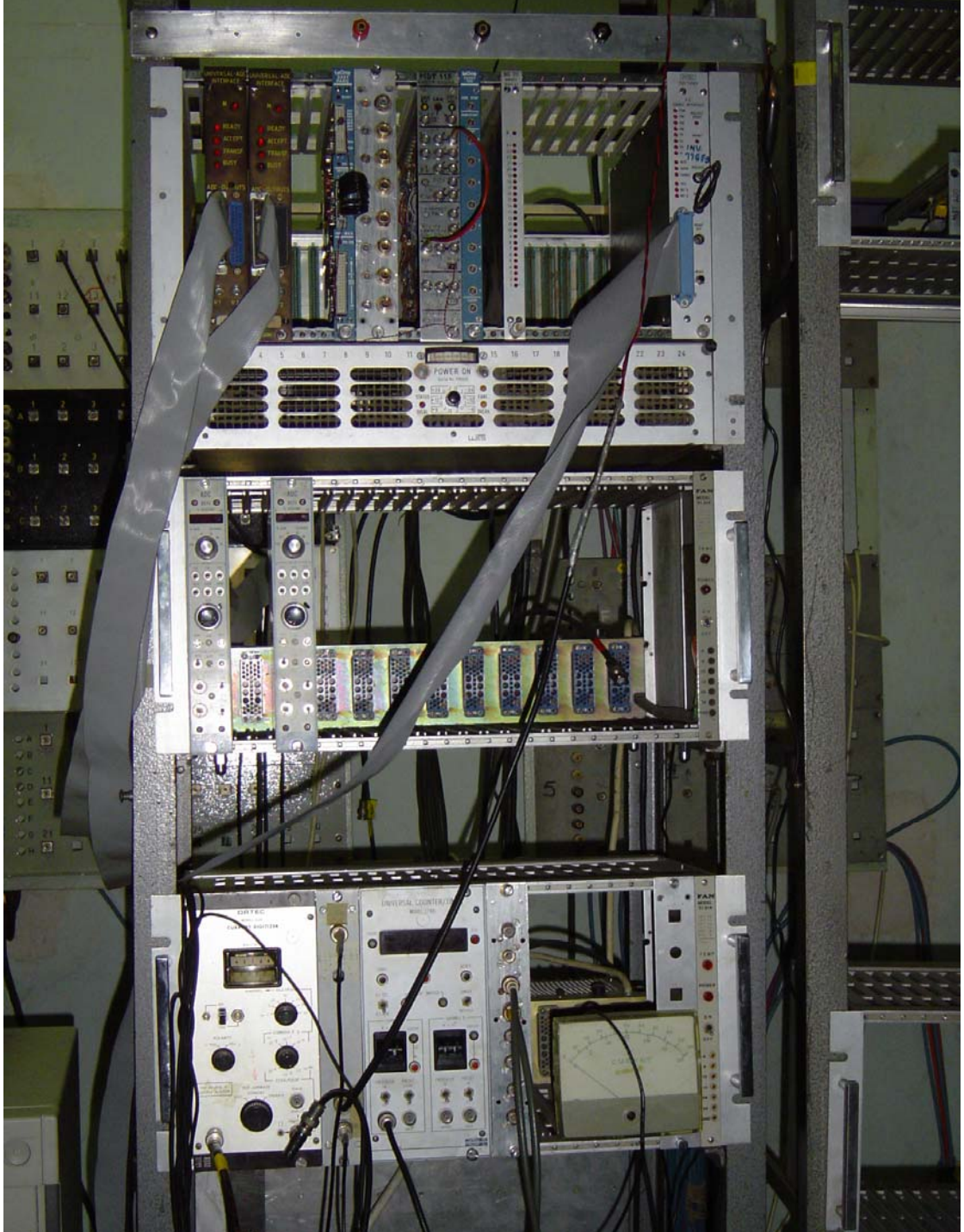
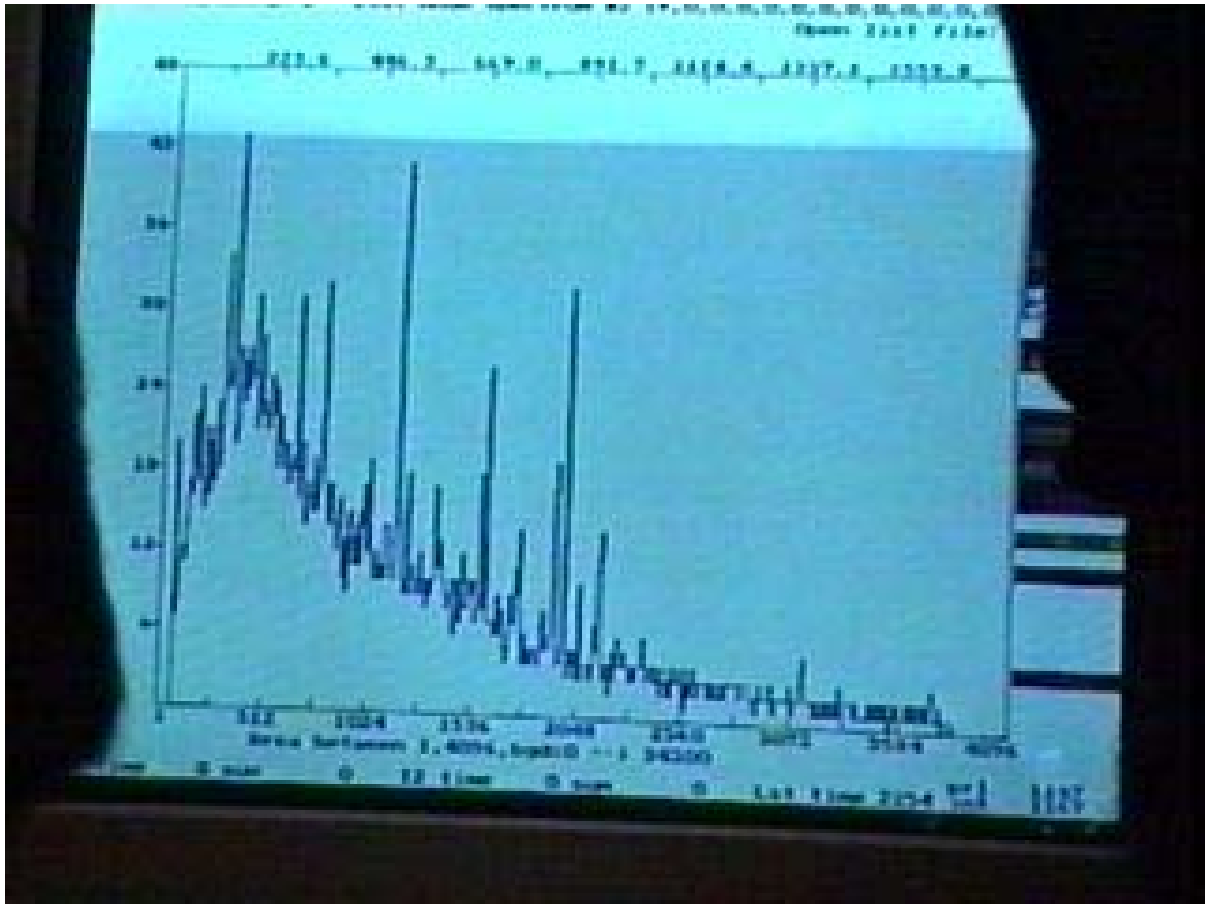


Multiparametric data acquisition system

- 2 8K ADC's
- 1 multi-ADC (8 x 4K)
- 1 multi-TDC (8 ways)



Software for acquisition and data processing

(compatible with GASPWARE)

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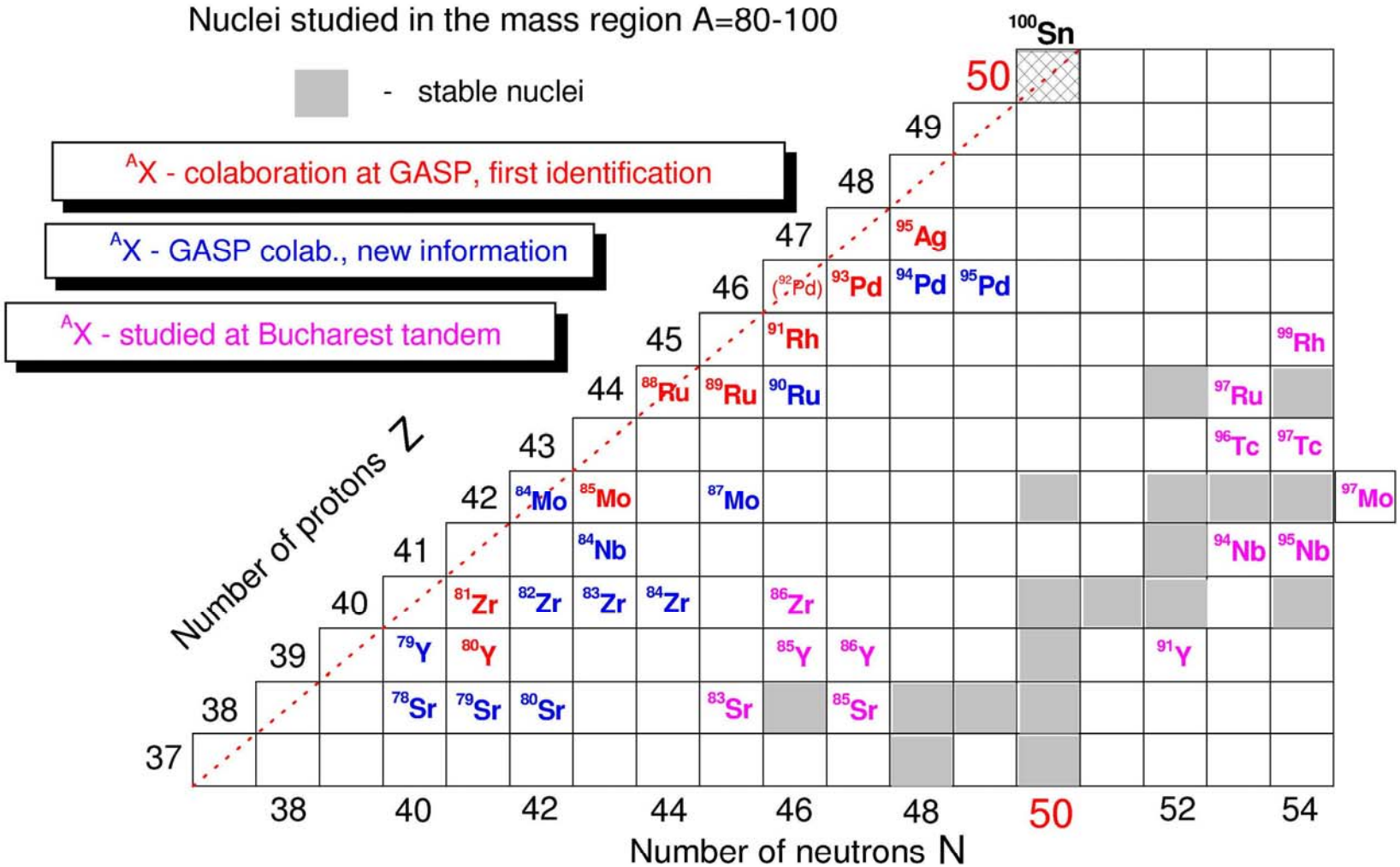
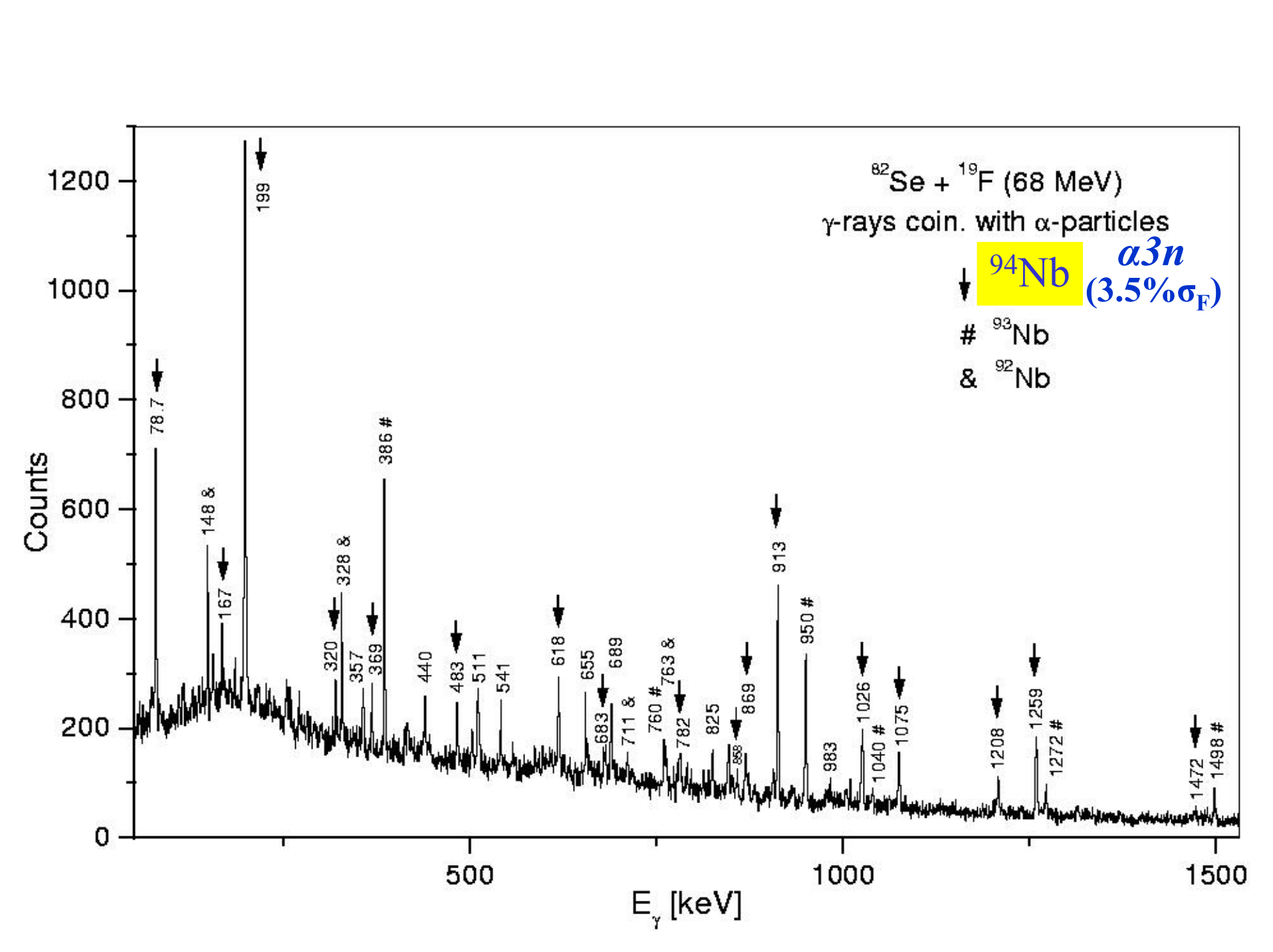
High spin γ-ray spectroscopy with heavy-ion fusion-evaporation reactions

- γ – ray excitation functions
- neutron - γ and charged particle – γ coincidences
  (*channel assignment*)
- γ – γ coincidences
  (*level & γ-decay scheme*)
- angular distributions, DCO ratios
  (*spin (parity) assignments*)
- DSAM, RDM
  (*lifetime measurements*)

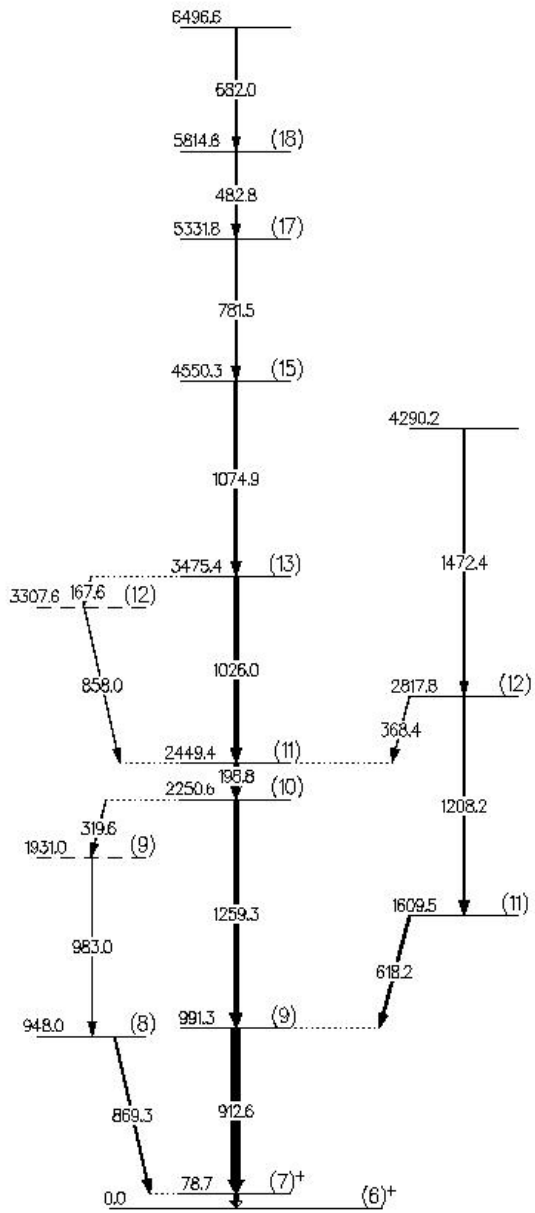

Nuclei studied in the mass region A=80-100
- stable nuclei
AX - colaboration at GASP, first identification
AX - GASP colab., new information
AX - studied at Bucharest tandem
100Sn
50
49
48
47
46
45
44
43
42
41
40
39
38
37
95Ag
(92Pd) 93Pd 94Pd 95Pd
91Rh 99Rh
88Ru 89Ru 90Ru 97Ru
96Tc 97Tc
84Mo 85Mo 87Mo 97Mo
84Nb 94Nb 95Nb
81Zr 82Zr 83Zr 84Zr 86Zr
79Y 80Y 85Y 86Y 91Y
78Sr 79Sr 80Sr 83Sr 85Sr
Number of protons Z
38 40 42 44 46 48 50 52 54
Number of neutrons N


82Se + 19F (68 MeV)
γ-rays coin. with α-particles
94Nb
α3n
(3.5%σF)
93Nb
& 92Nb
Counts
Eγ [keV]
0
200
400
600
800
1000
1200
500
1000
1500
78.7
148 &
167
199
320
328 &
357
369
386 #
440
483
511
541
618
655
683
689
711 &
760 #
763 &
782
825
869
913
950 #
983
1026
1040 #
1075
1208
1259
1272 #
1472
1498 #

53

^{94}Nb

41



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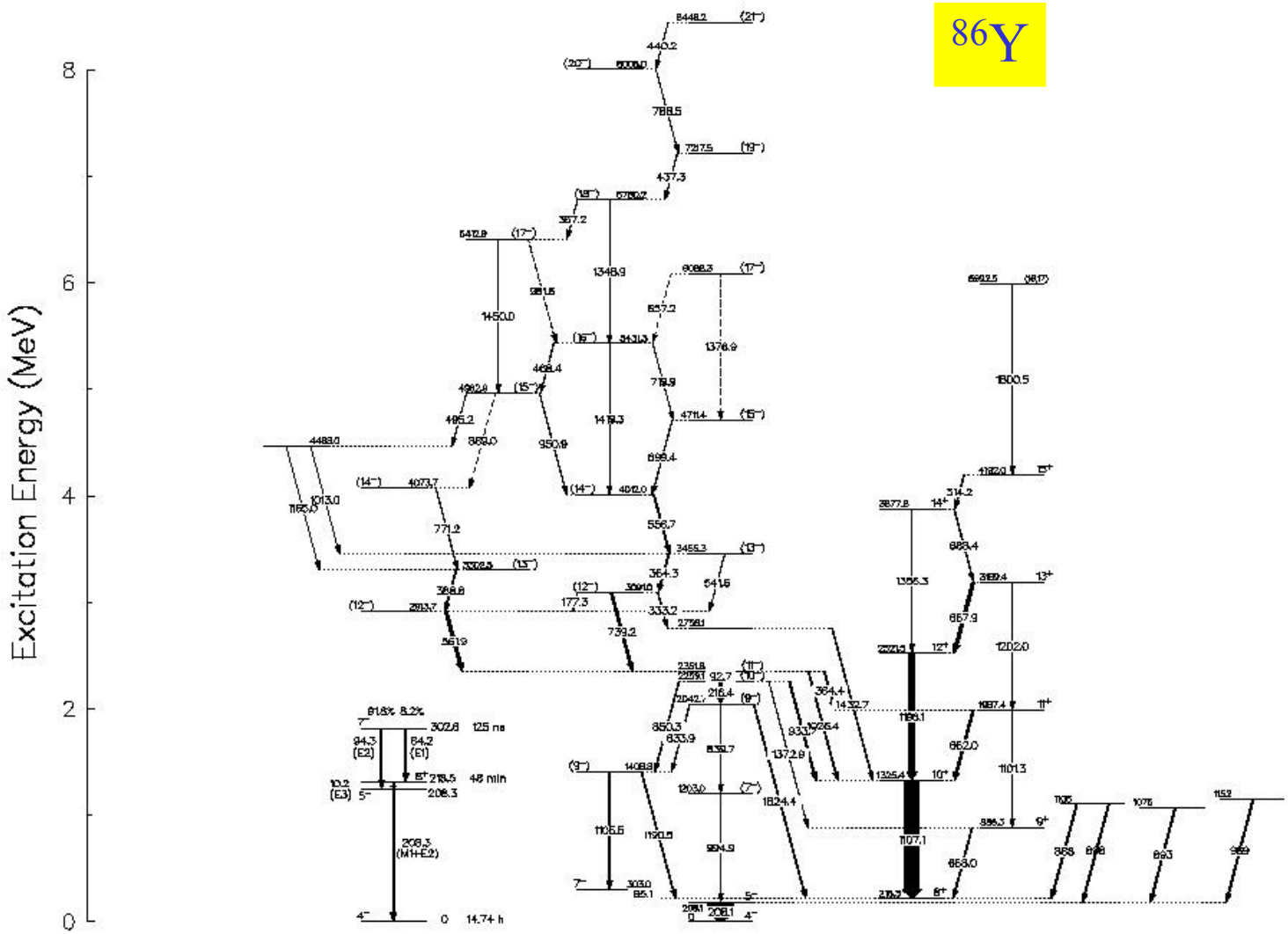
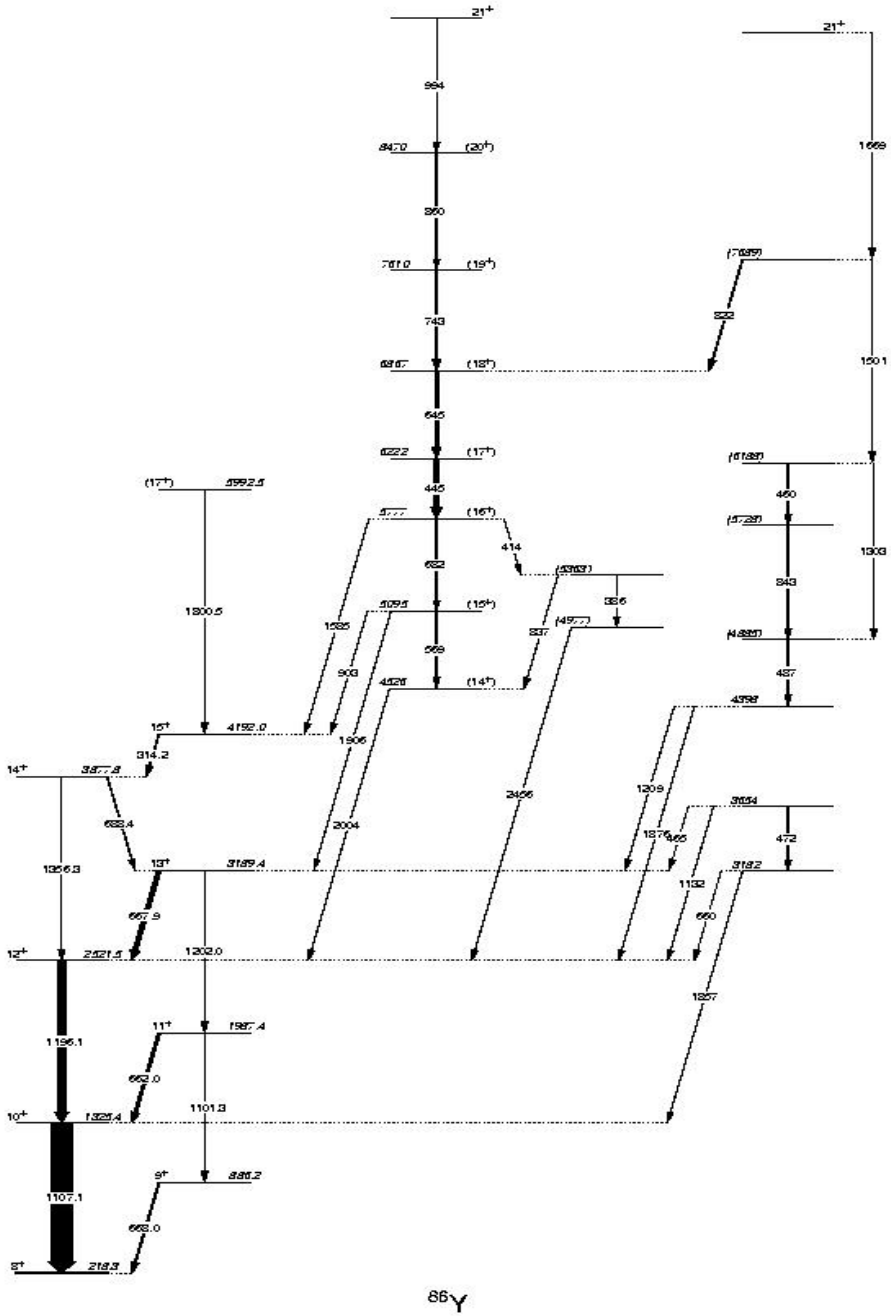
$^{73}Ge(^{16}O,p2n)$ 60 MeV; $^{76}Ge(^{14}N,4n)$ 52 MeV



$^{63}Cu(^{28}Si,4pn)$ 130 MeV (GASP)



86Y

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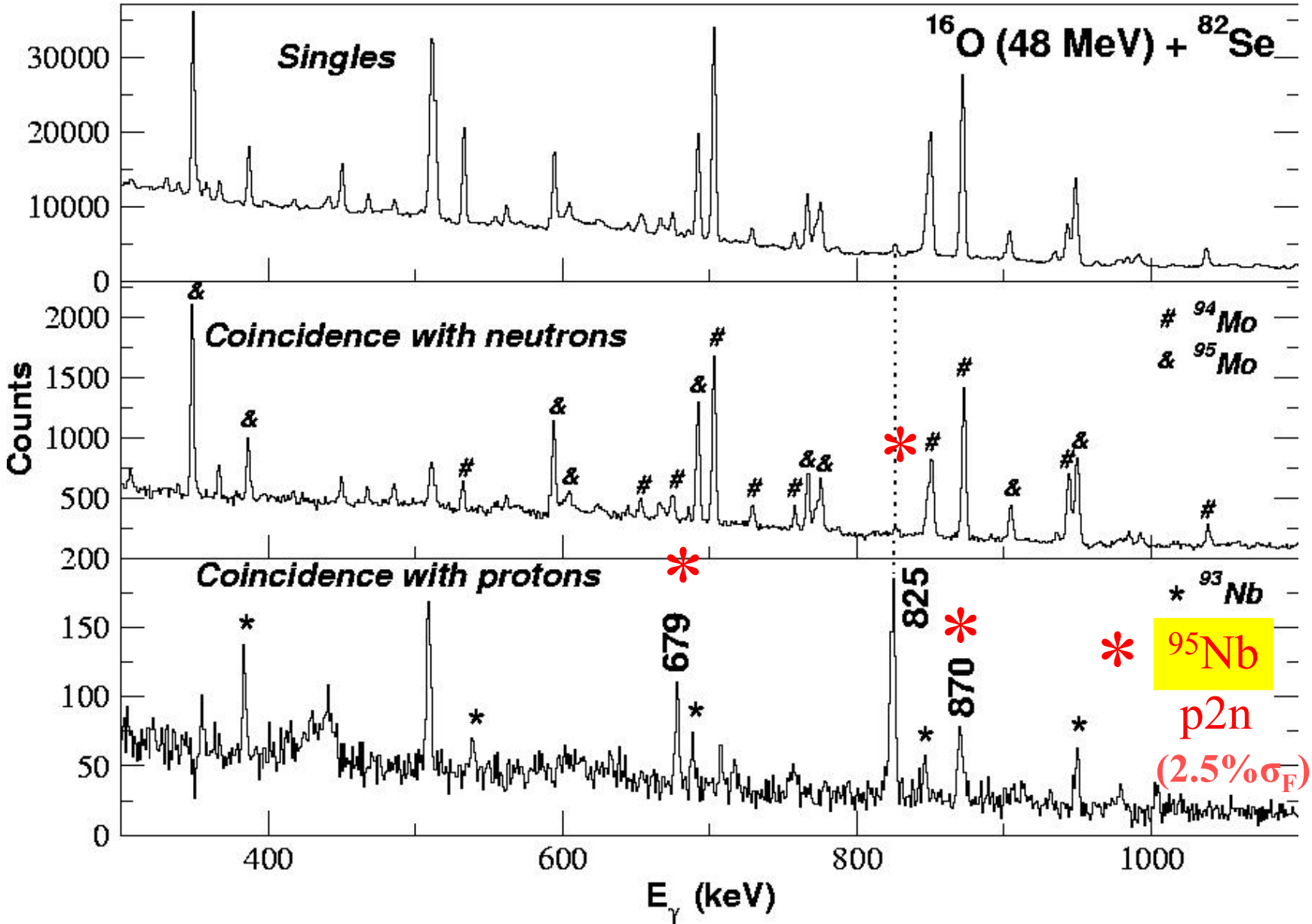
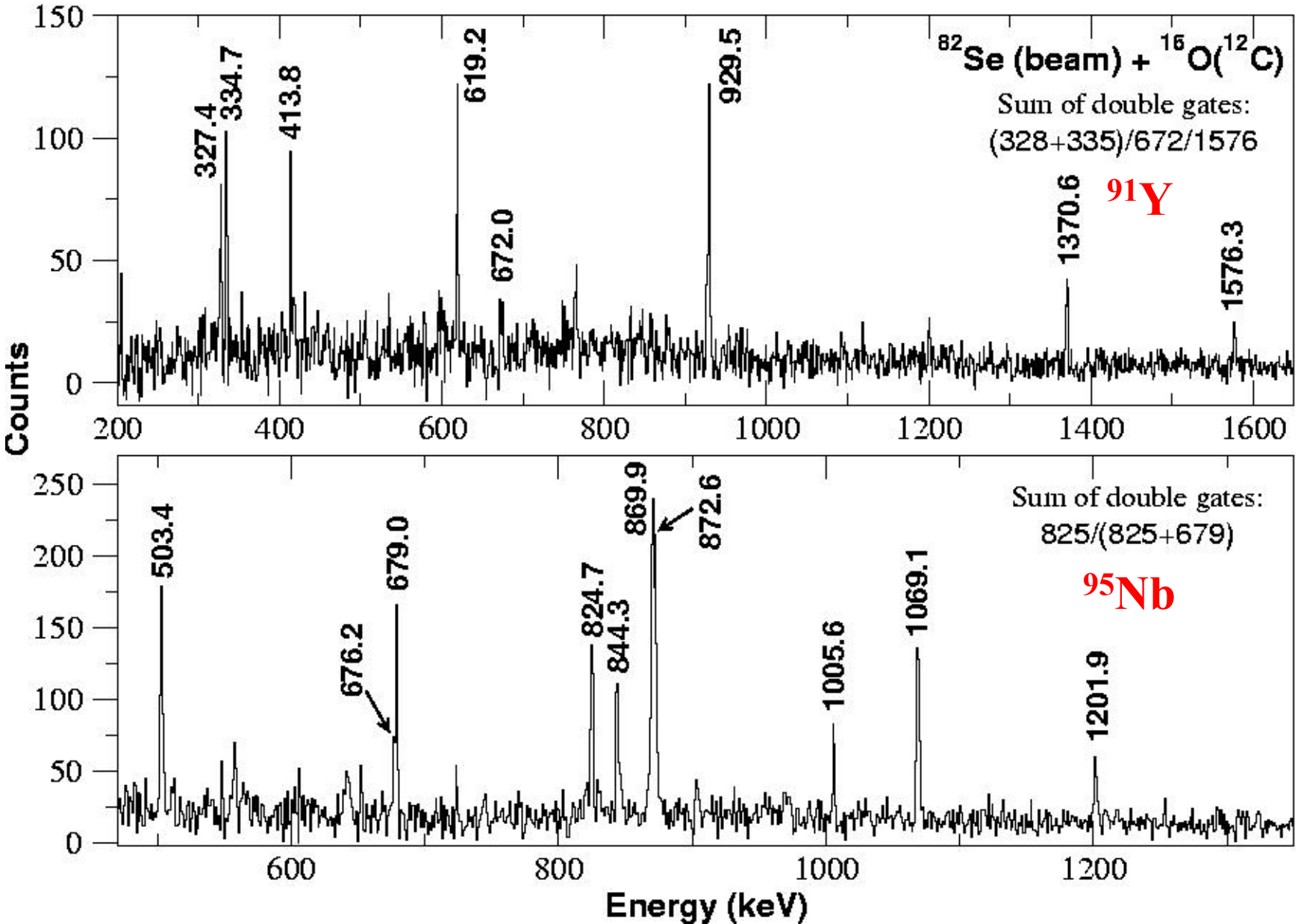
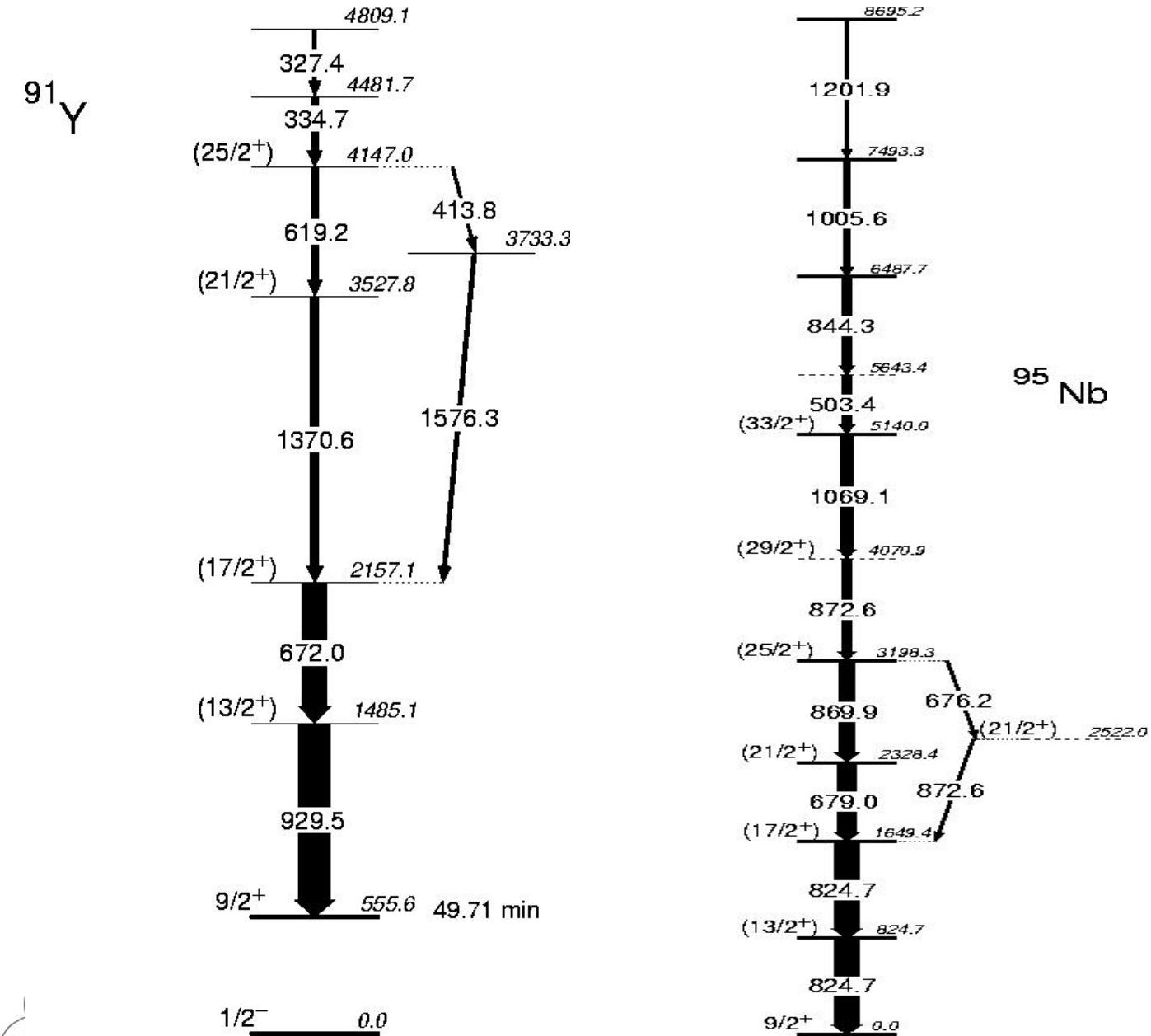
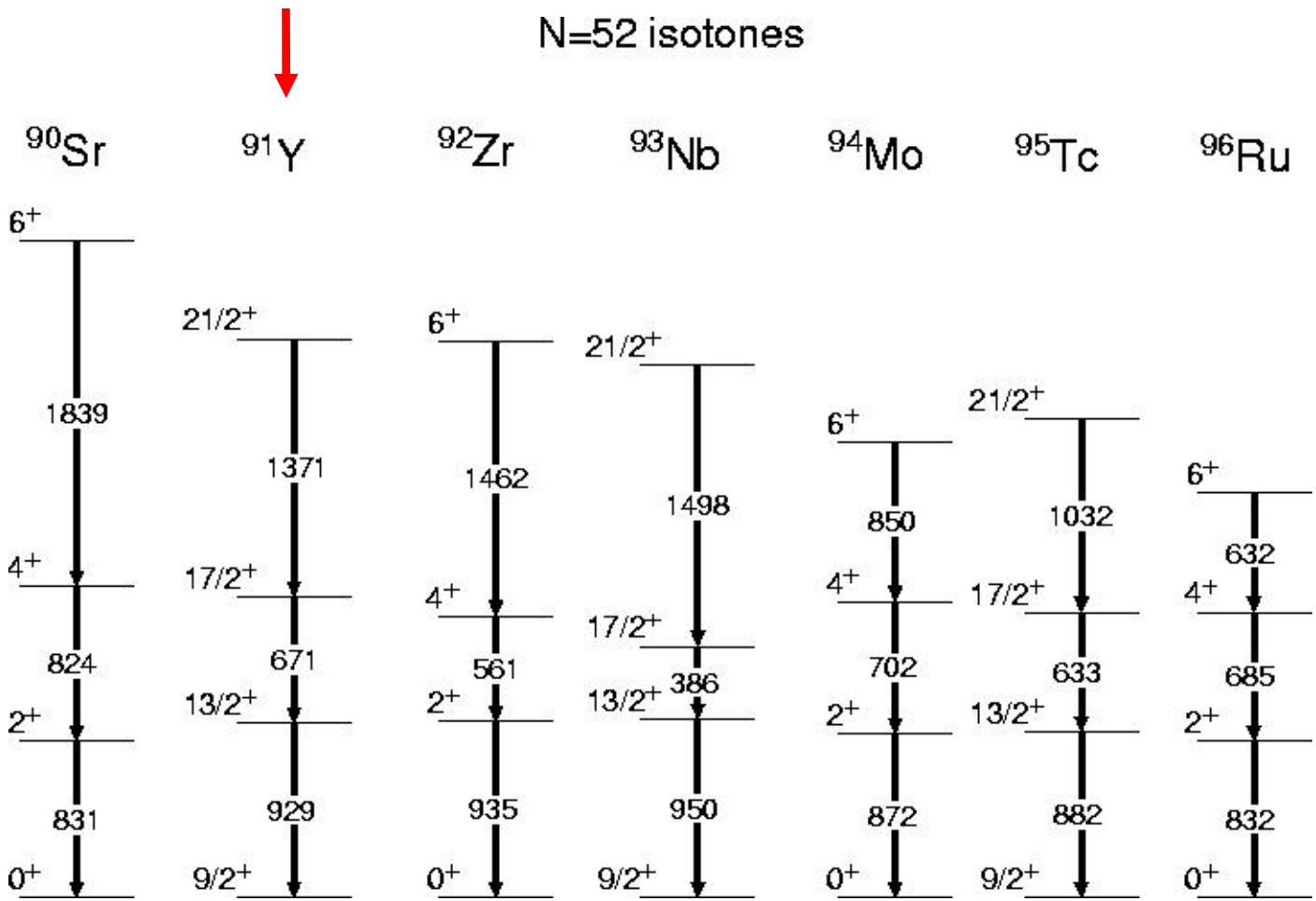

Singles
^{16}O (48 MeV) + ^{82}Se
Coincidence with neutrons
^{94}Mo
& ^{95}Mo
Coincidence with protons
* ^{93}Nb
* ^{95}Nb
p2n
(2.5%σ$_F$)
679
825
870
Counts
E$_\gamma$ (keV)

^{82}Se beam + Oxygen contamin. of Os target, GASP exp.

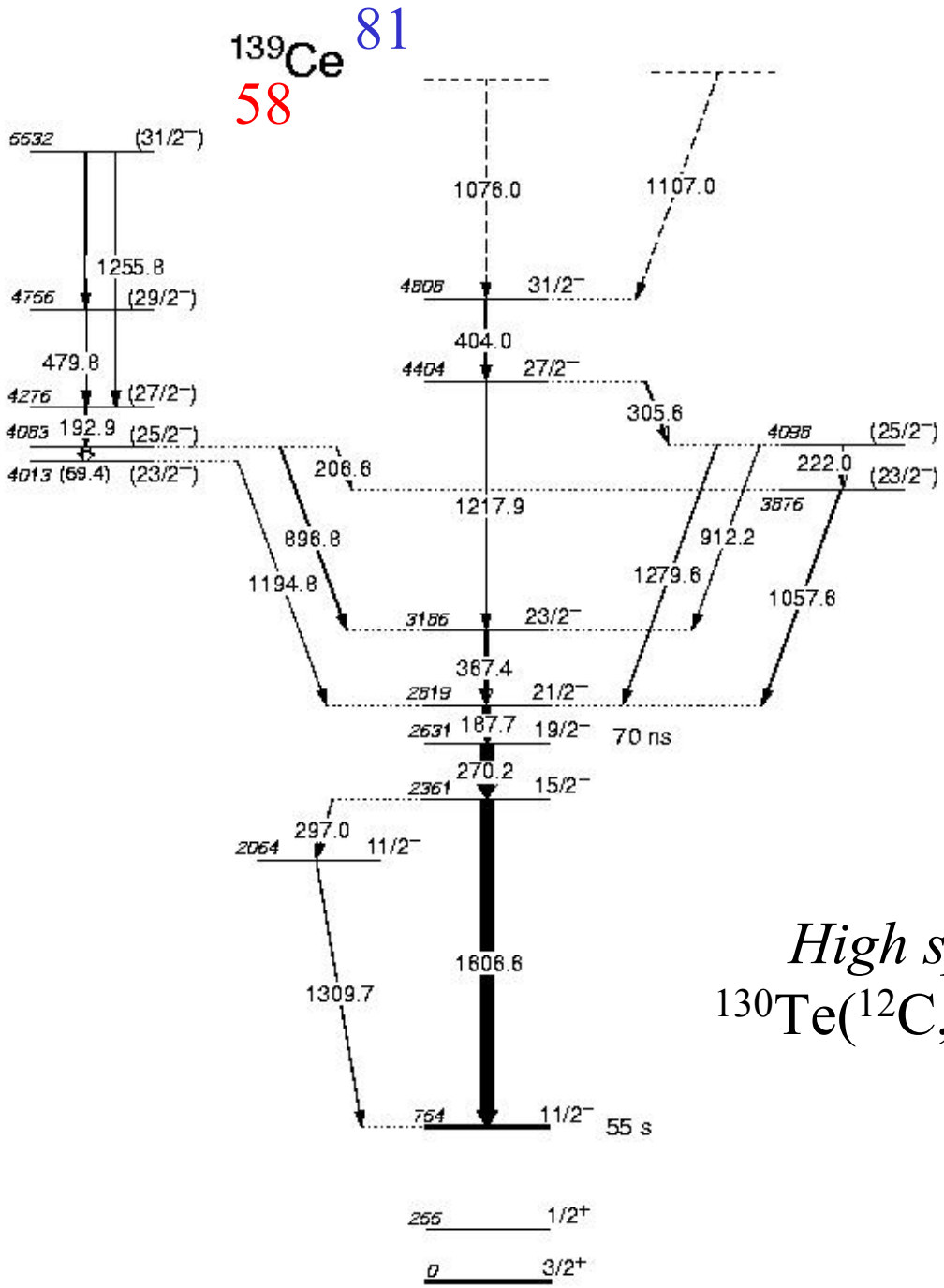



91 Y
4809.1
327.4
4481.7
334.7
(25/2+)
4147.0
413.8
3733.3
619.2
(21/2+)
3527.8
1576.3
1370.6
(17/2+)
2157.1
672.0
(13/2+)
1485.1
929.5
9/2+
555.6
49.71 min
1/2−
0.0
8695.2
1201.9
7493.3
1005.6
6487.7
844.3
5643.4
503.4
(33/2+)
5140.0
95 Nb
1069.1
(29/2+)
4070.9
872.6
(25/2+)
3198.3
676.2
869.9
(21/2+)
2522.0
(21/2+)
2328.4
872.6
679.0
(17/2+)
1649.4
824.7
(13/2+)
824.7
824.7
9/2+
0.0

IFIN - HH


N=52 isotones
90Sr
91Y
92Zr
93Nb
94Mo
95Tc
96Ru
6+
1839
4+
824
2+
831
0+
21/2+
1371
17/2+
671
13/2+
929
9/2+
6+
1462
4+
561
2+
935
0+
21/2+
1498
17/2+
386
13/2+
950
9/2+
6+
850
4+
702
2+
872
0+
21/2+
1032
17/2+
633
13/2+
882
9/2+
6+
632
4+
685
2+
832
0+

IFIN - HH



High spins:

^{130}Te(^{12}C,3nγ), 50 MeV

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Lifetimes (nuclei with A~90) - plunger

Low spin γ-ray spectroscopy with (p,n γ) reactions

- *$n - \gamma$, $\gamma - \gamma$ coincidences*
- *non-selective reaction: all (low-spin) states*
- *threshold reaction -> DSAM lifetime measurements*

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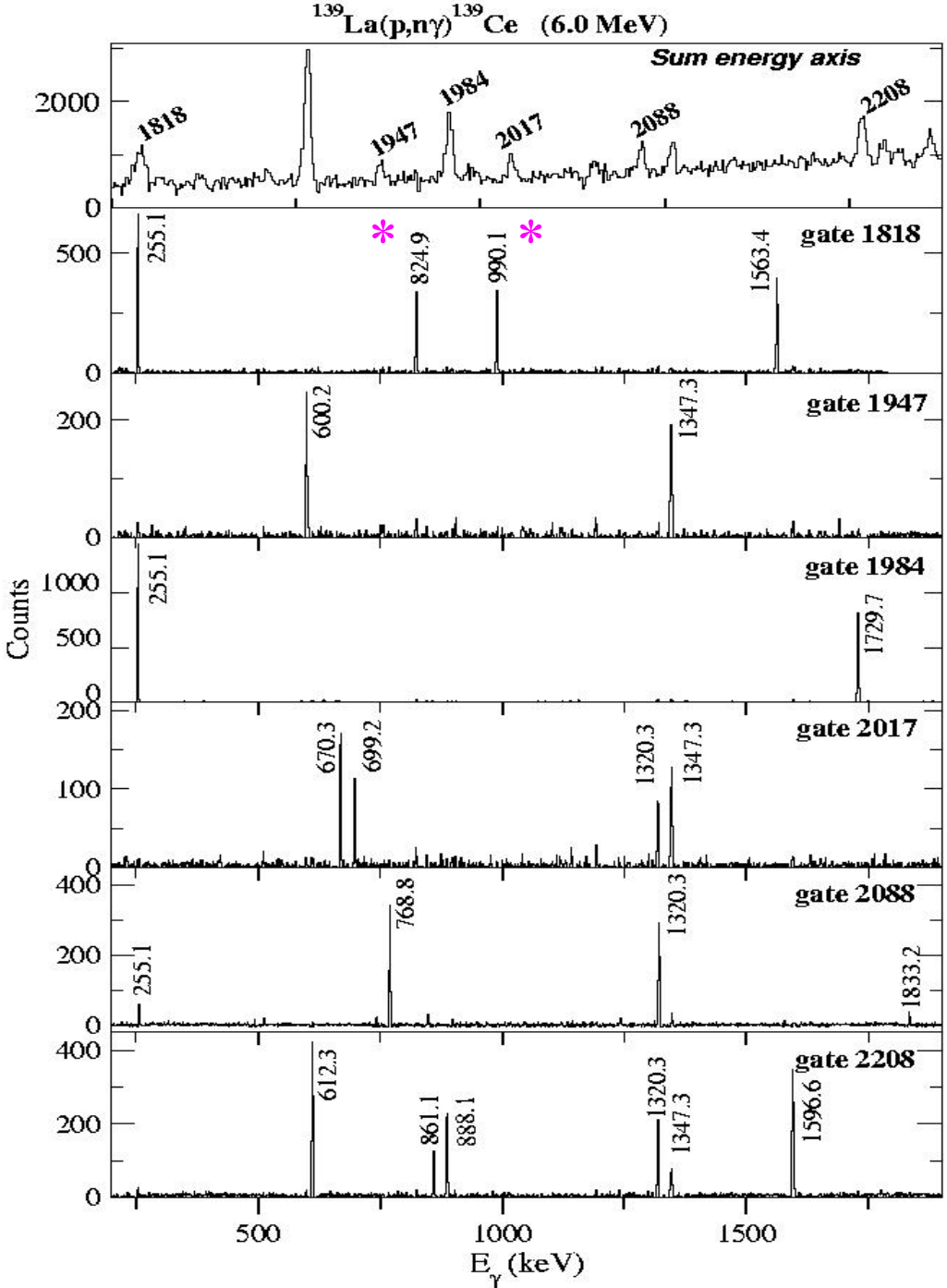
TSC
(two-step cascade matrix)



Levels:
1818 keV
* 2569 keV -> isomer 11/2-, 754 keV

Level 2197

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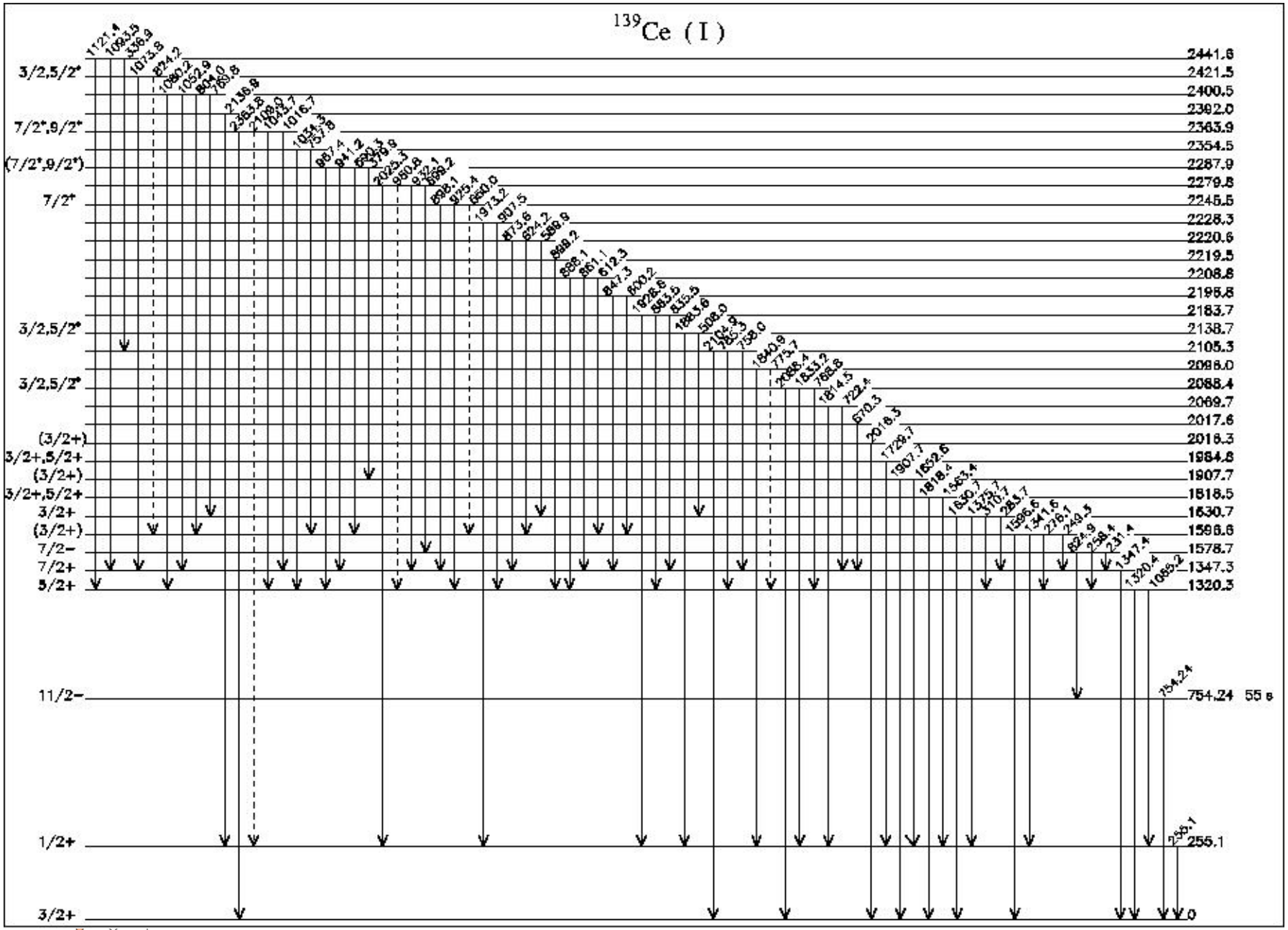
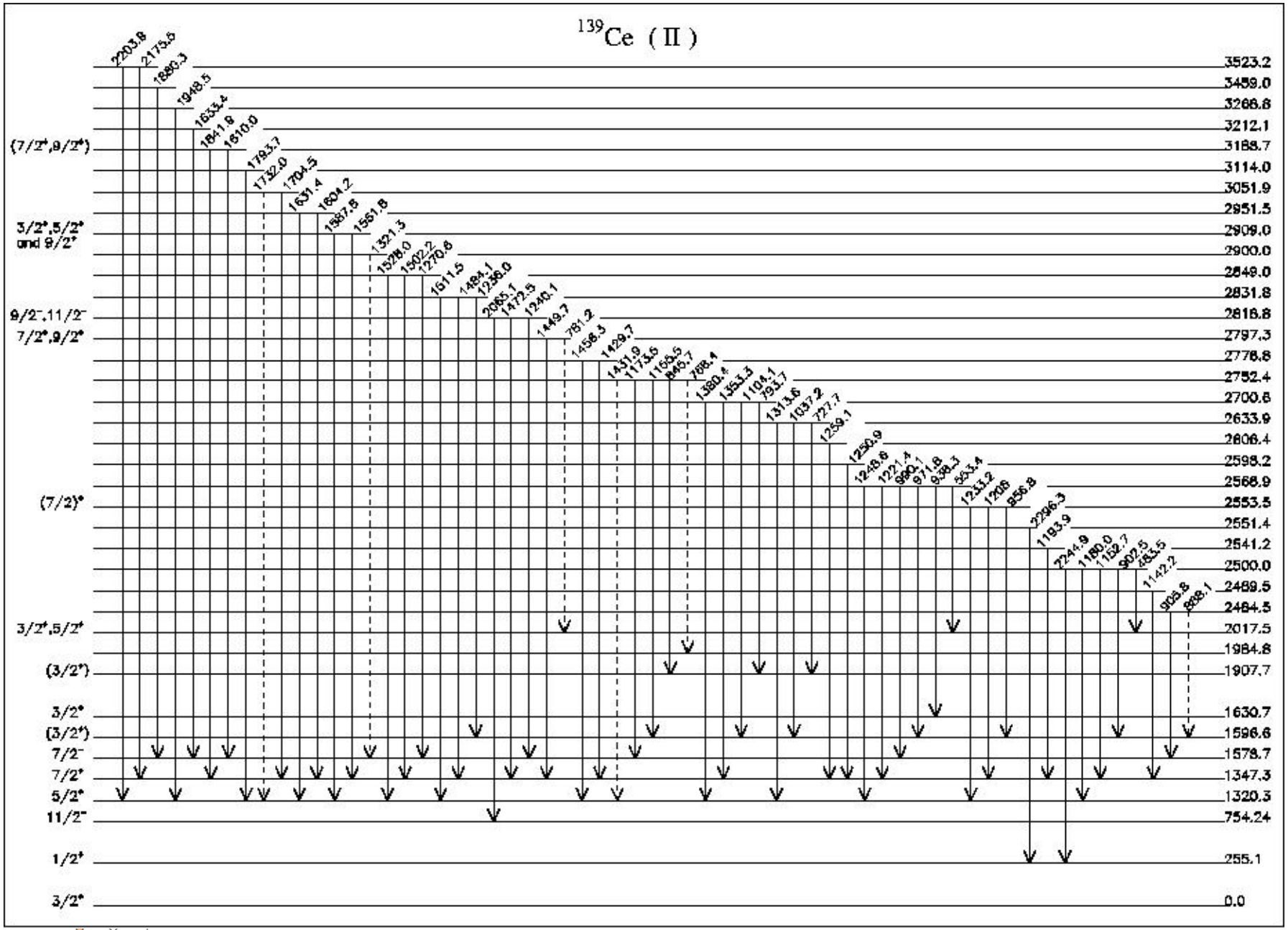
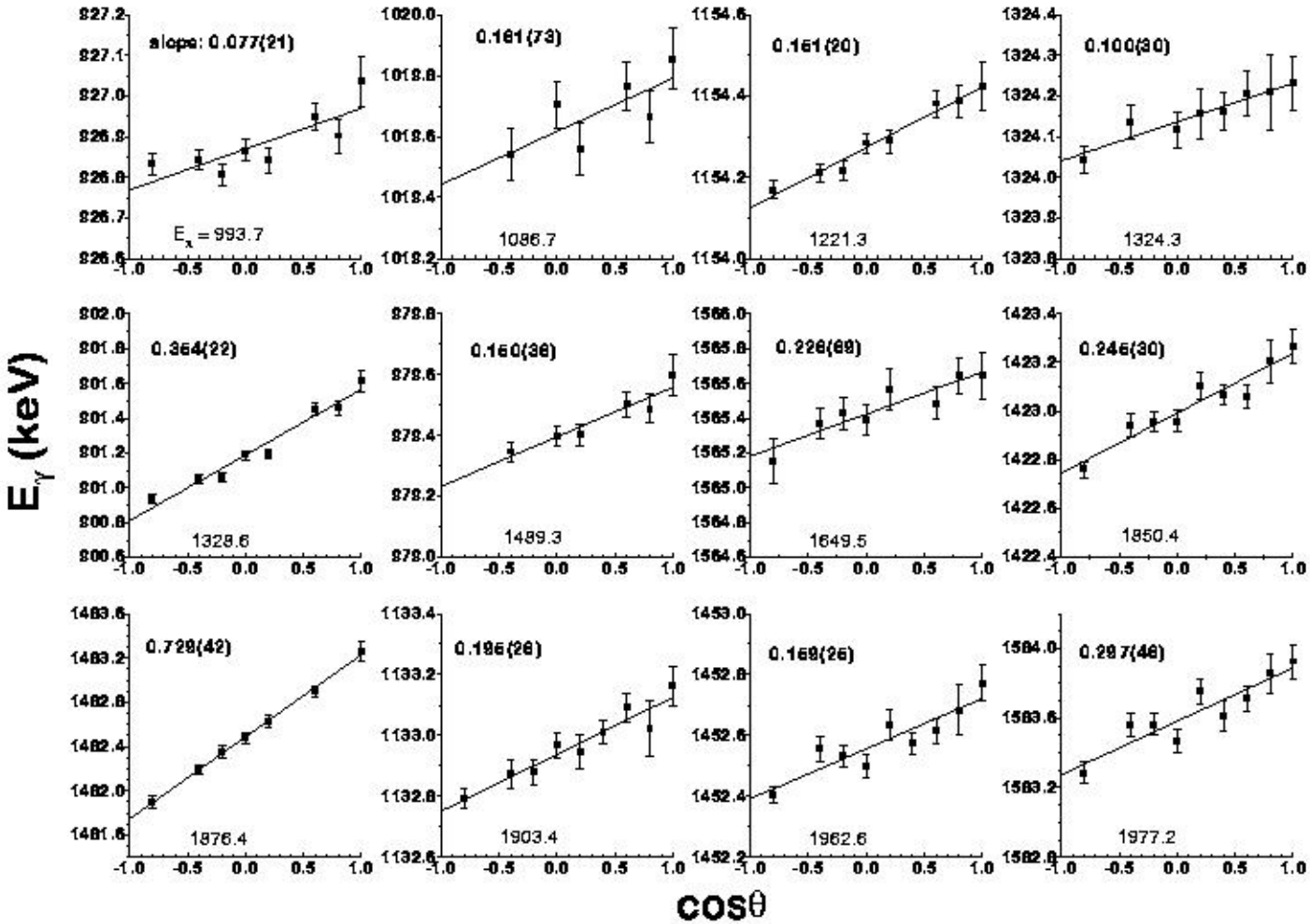
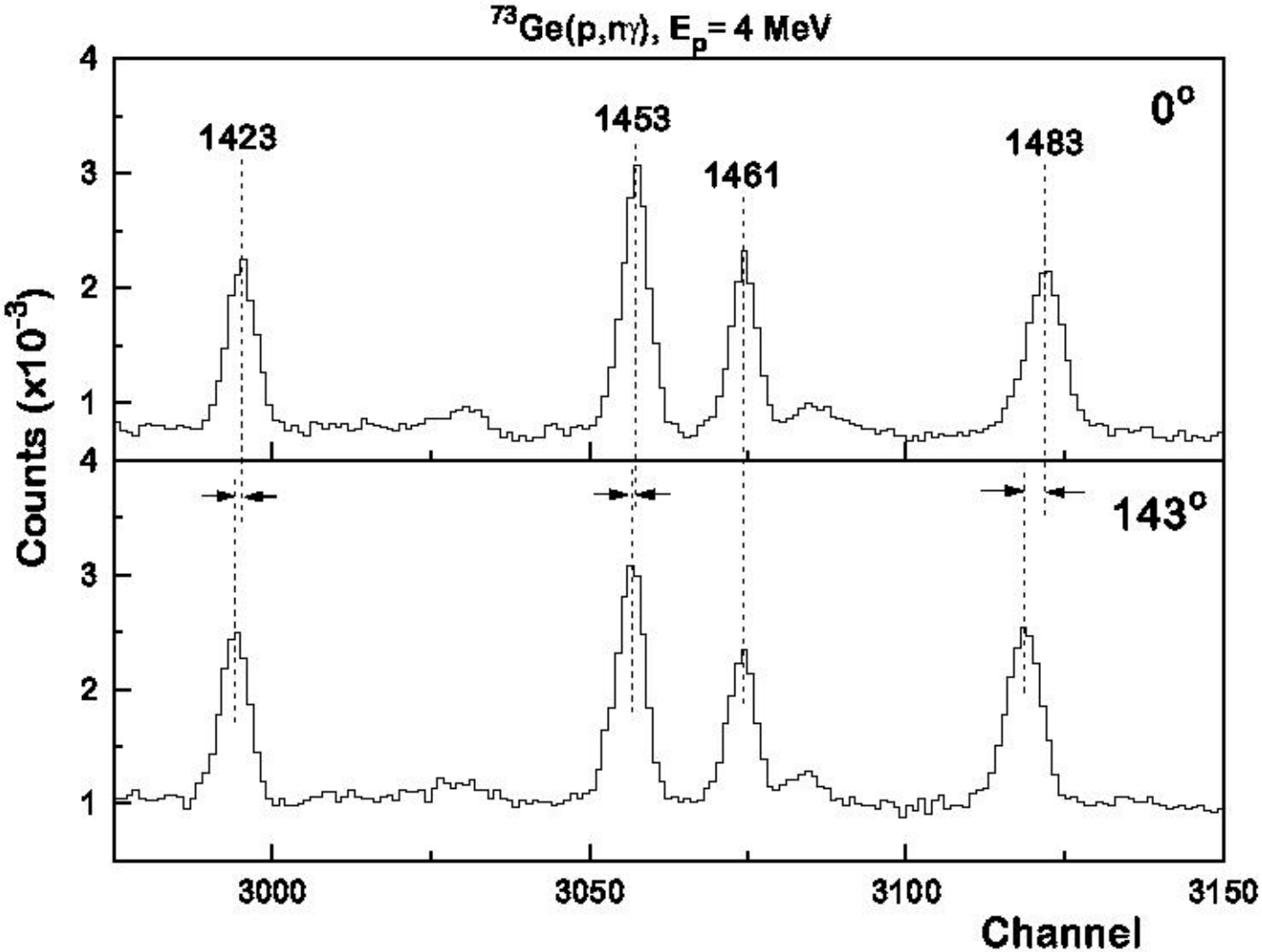

139Ce (I)
3/2,5/2+
7/2+,9/2+
(7/2+,9/2+)
7/2+
3/2,5/2+
3/2,5/2+
(3/2+)
3/2+,5/2+
(3/2+)
3/2+,5/2+
3/2+
(3/2+)
7/2−
7/2+
5/2+
11/2−
1/2+
3/2+
2441.6
2421.5
2400.5
2392.0
2363.9
2354.5
2287.9
2279.8
2245.5
2228.3
2220.6
2219.5
2208.8
2195.8
2183.7
2138.7
2105.3
2098.0
2088.4
2069.7
2017.6
2016.3
1984.8
1907.7
1818.5
1630.7
1596.6
1578.7
1347.3
1320.3
754.24 55 s
255.1
0


139Ce (II)
2203.8
2175.5
1880.3
1948.5
1633.4
1841.8
1810.0
1783.7
1732.0
1704.5
1631.4
1604.2
1587.8
1561.8
1321.3
1528.0
1502.2
1270.6
1611.5
1484.1
1236.0
2065.1
1472.5
1240.1
1449.7
781.2
1458.3
1429.7
1431.9
1173.5
1155.5
845.7
768.4
1380.4
1353.3
1104.1
793.7
1313.6
1037.2
727.7
1259.1
1250.9
1248.6
1221.4
980.1
971.8
938.3
553.4
1233.2
1206
856.8
2296.3
1193.9
2244.9
1180.0
1152.7
902.5
853.5
1142.2
905.8
868.1
3523.2
3459.0
3266.6
3212.1
3188.7
3114.0
3051.9
2951.5
2909.0
2900.0
2849.0
2831.8
2818.8
2797.3
2776.8
2752.4
2700.6
2633.9
2606.4
2598.2
2568.9
2553.5
2551.4
2541.2
2500.0
2489.5
2484.5
2017.5
1984.8
1907.7
1630.7
1596.6
1578.7
1347.3
1320.3
754.24
255.1
0.0
(7/2+,9/2+)
3/2+,5/2+ and 9/2+
9/2-,11/2-
7/2+,9/2+
(7/2)+
3/2+,5/2+
(3/2+)
3/2+
(3/2+)
7/2-
7/2+
5/2+
11/2-
1/2+
3/2+

DSAM for $^{73}Ge(p,n\gamma)^{73}As$, $E_p = 4$ MeV




^{73}Ge(p,nγ), E_p= 4 MeV
0°
143°
1423
1453
1461
1483
Counts (x10^{-3})
Channel
3000
3050
3100
3150
1
2
3
4

Beta decay studies

^{100}Ru – X(5) nucleus?

^{100}Rh (1^-, 20.8h) $\xrightarrow{\beta^+}$ ^{100}Ru

(^{100}Ru(d,2n), E_d=20 MeV;
^{100}Ru(p, n), E_p=10 MeV)

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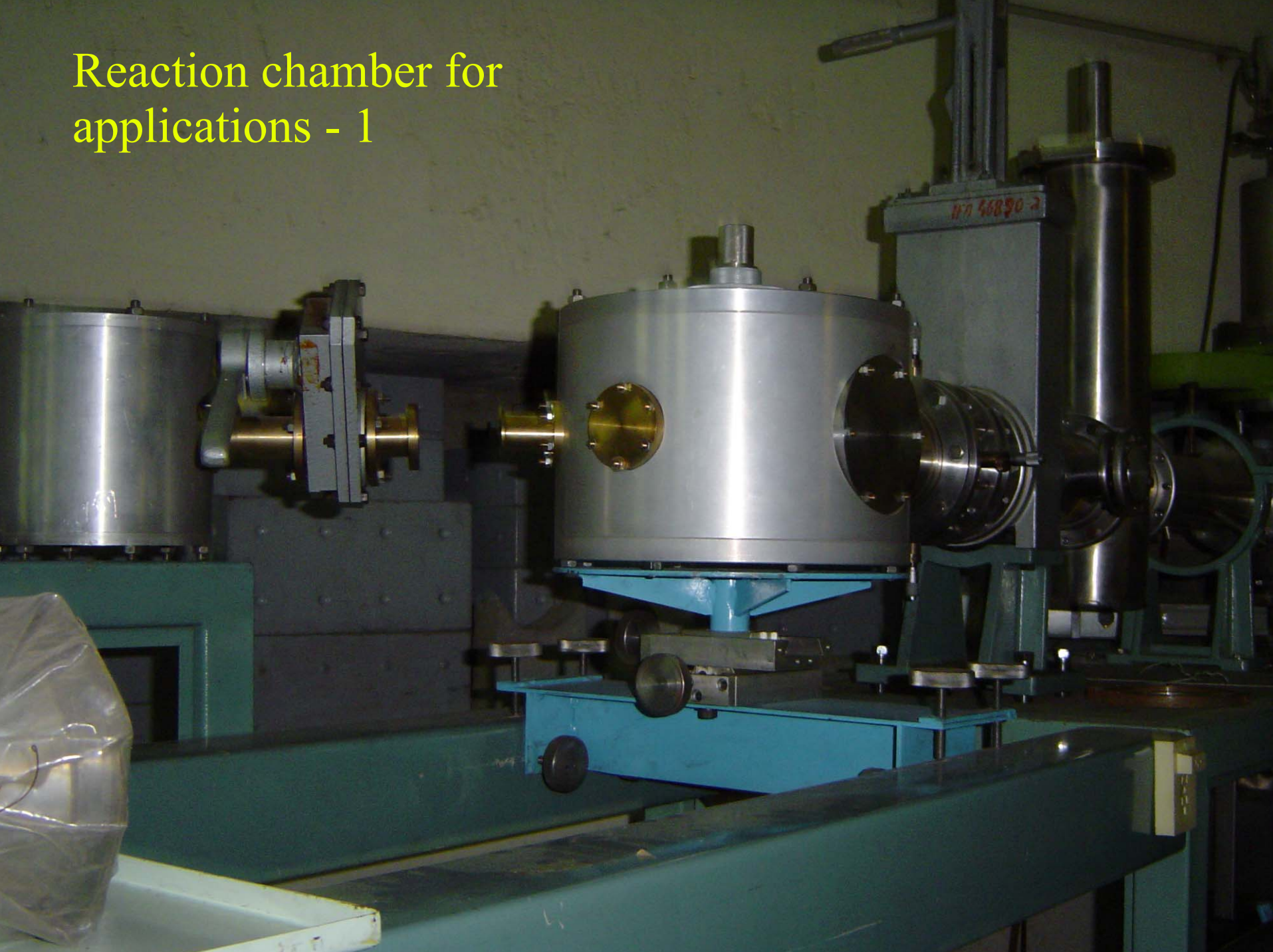
Aplications of nuclear methods

Methods (high-precision measrements of various materials):

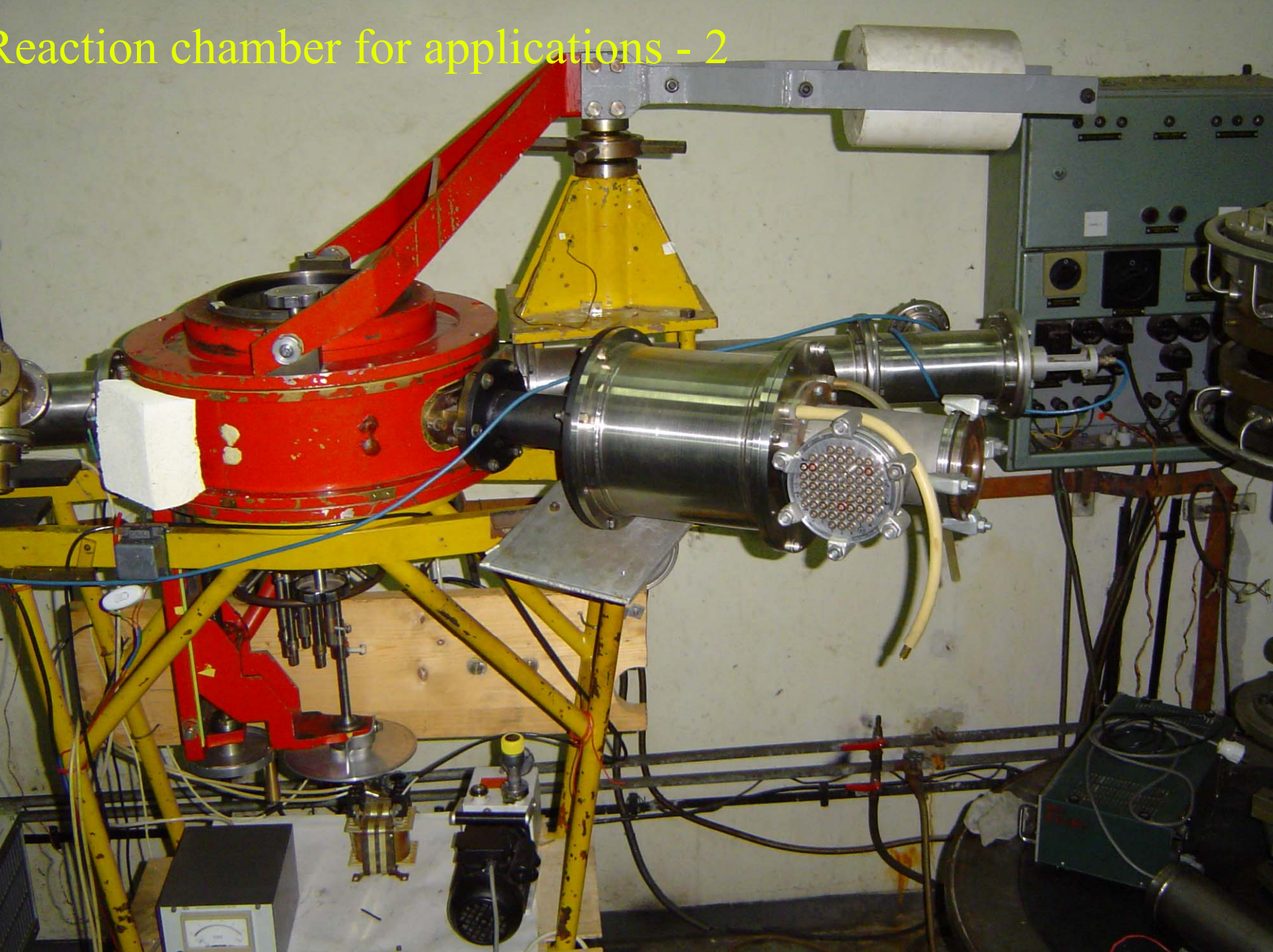
- RBS/Channeling (Rutherford back-scattering/channeling);
- NRA (Nuclear Reaction Analysis)
- ERDA (Elastic Recoil Detection Analysis)
- PIXE (Particle Induced X-Ray Emission)
- AMS (Accelerator Mass Spectrometry)

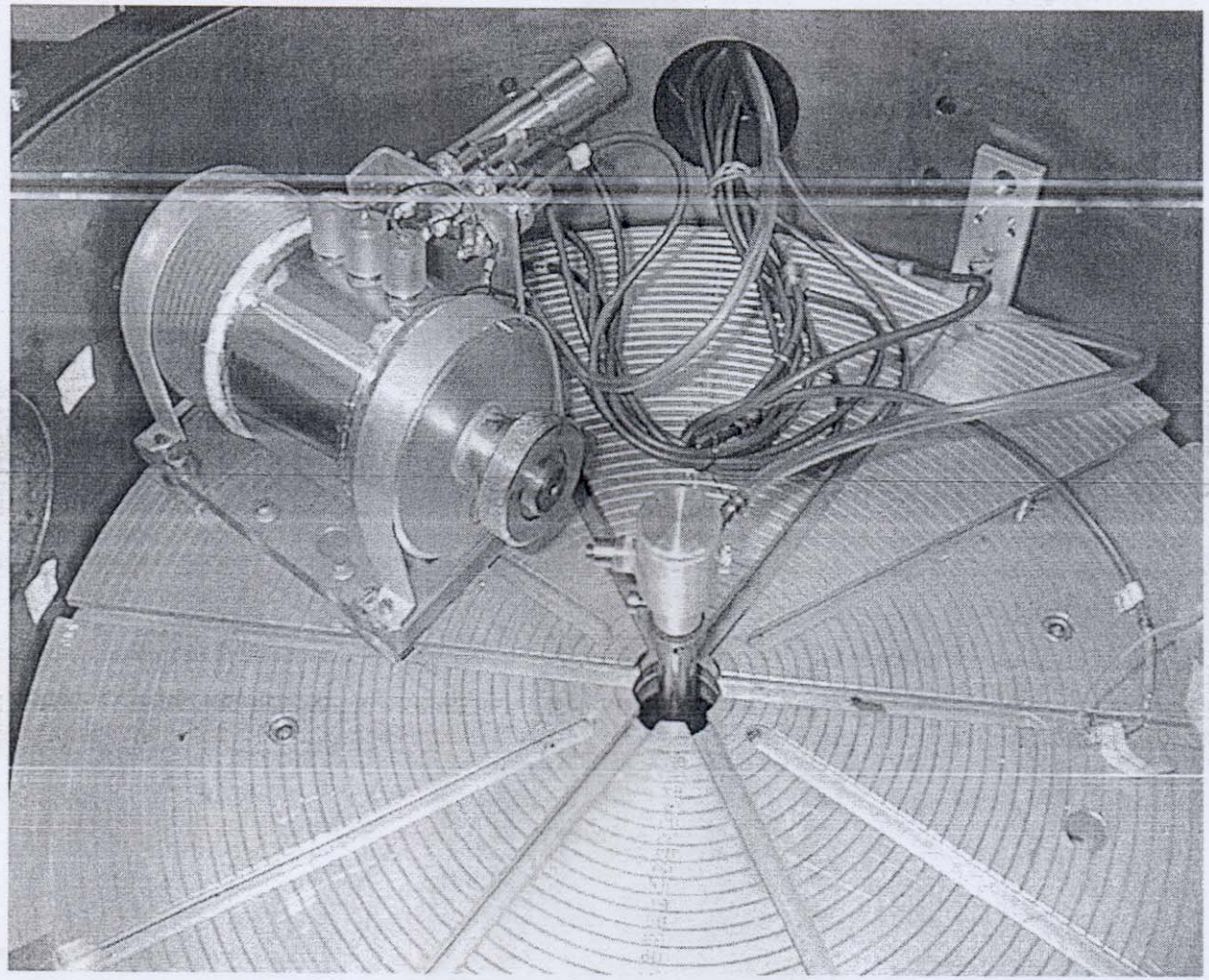
Aplications: solid state physics, microelectronics, surface analysis, radioactive waste confinement materials, archeology, biology, medicine, agriculture, etc.)

Reaction chamber for applications - 1



Reaction chamber for applications - 2





Chamber for ERDA on gas samples

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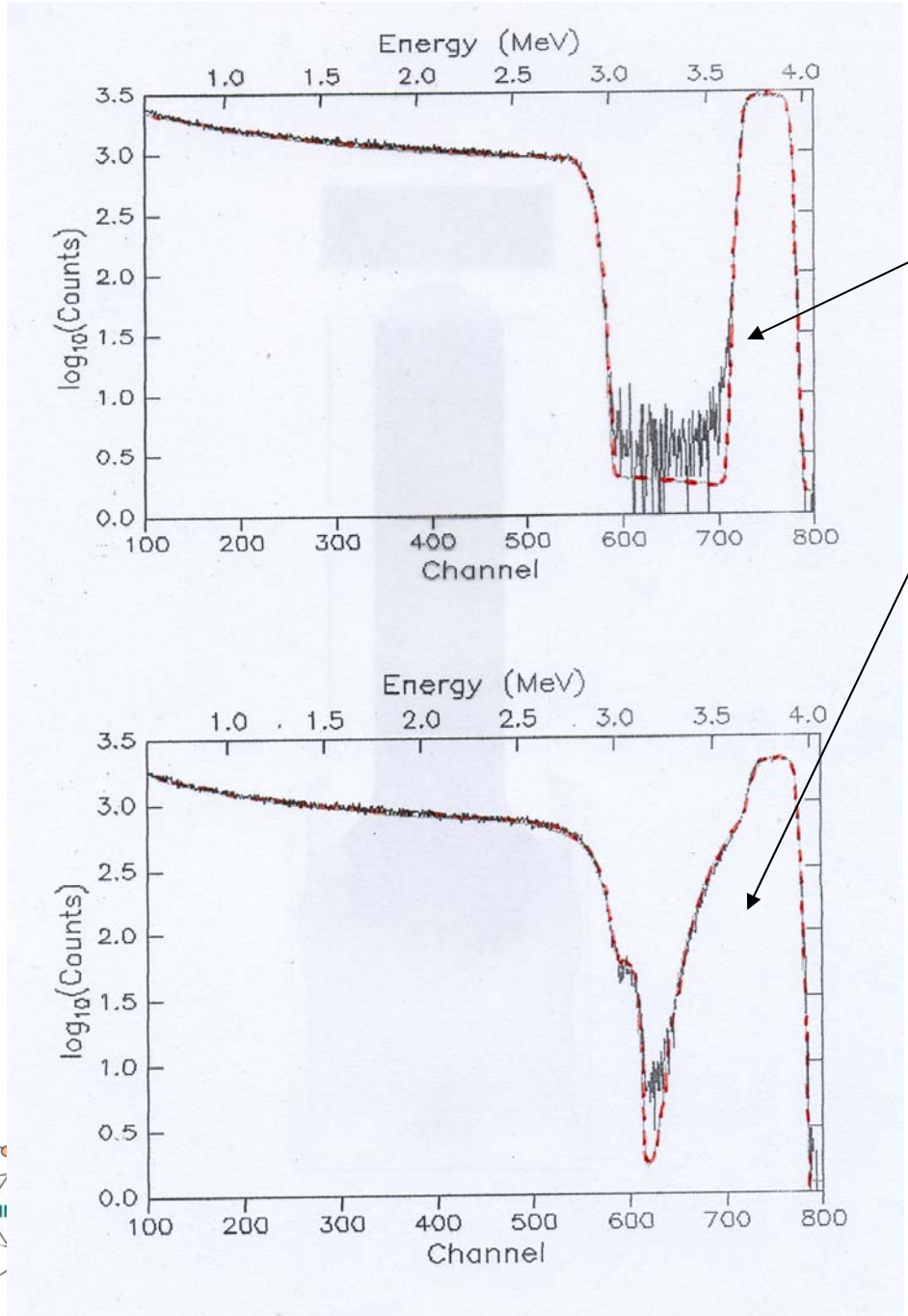

Peak
Au

RBS measurement

(Ga-As with Gold layer:

with thermal treatment (up)

without thermal (down)

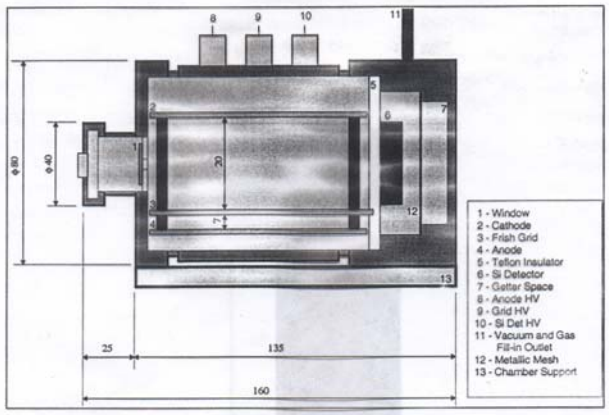

Figure 3.

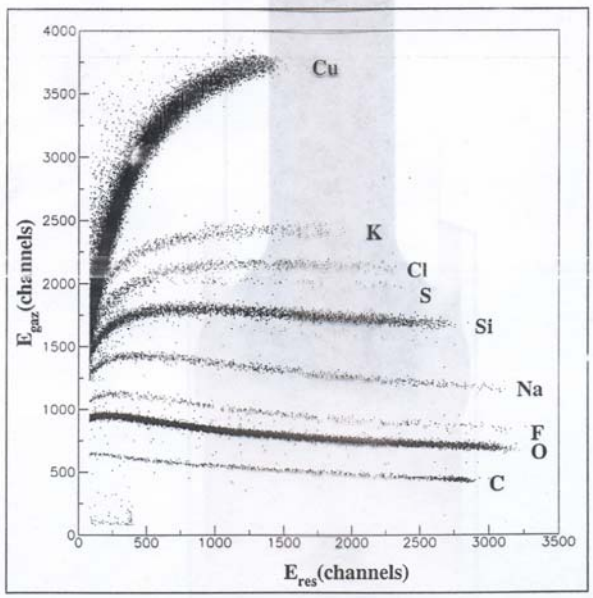

Figure 4.

RBS measurements

(glass with Cu insertion)


AMS ion source

END


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