THE BUCHAREST FN-TANDEM electrostatic ACCELERATOR

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General informations

- IFIN-HH ⇒ National Laboratory (ANCS)
- IFIN-HH located at about 15 km south-west of Bucharest in a small town called Magurele (the belt-way of Bucharest)
- FN-Tandem Van de Graaff electrostatic accelerator ⇒ legal status of "National nuclear installation" – special funds for maintenance and operation under constrain to provide free access at beams for universities and research institutes (not free for commercial users).
- FN-Tandem ⇒1974 (HVEC – USA) – several breakdowns (earthquakes) and upgrades

- 1974 – **2 MV**
- 2007 – **9 MV**

- **3 ion sources:**
  - duoplasmatron (HVEC)
  - sputtering (NEC)
  - AMS ultraclean (sputtering)
- **beams:** p to Au
  (no noble gases)
- **foil and gas stripping**
- **7 beamlines**

Anti-seismic protection (home made)

Costs (ANCS)

- Maintenance and operation

≈300.000 €/year

- operators & workshops (salaries, materials, etc.)
- SF6
- Power (~ 100 kW)
- infrastructure

- 2006 first major refurbishing:

≈ 1.000.000 €

- Vacuum systems
- Power supplies
- Infrastructure
- Belt charging to pelletron
- New Sputtering source (NEC)

14GHz Electronic Cyclotron Resonance Ion Source (ECRIS)

Experimental Program at Tandem accelerator

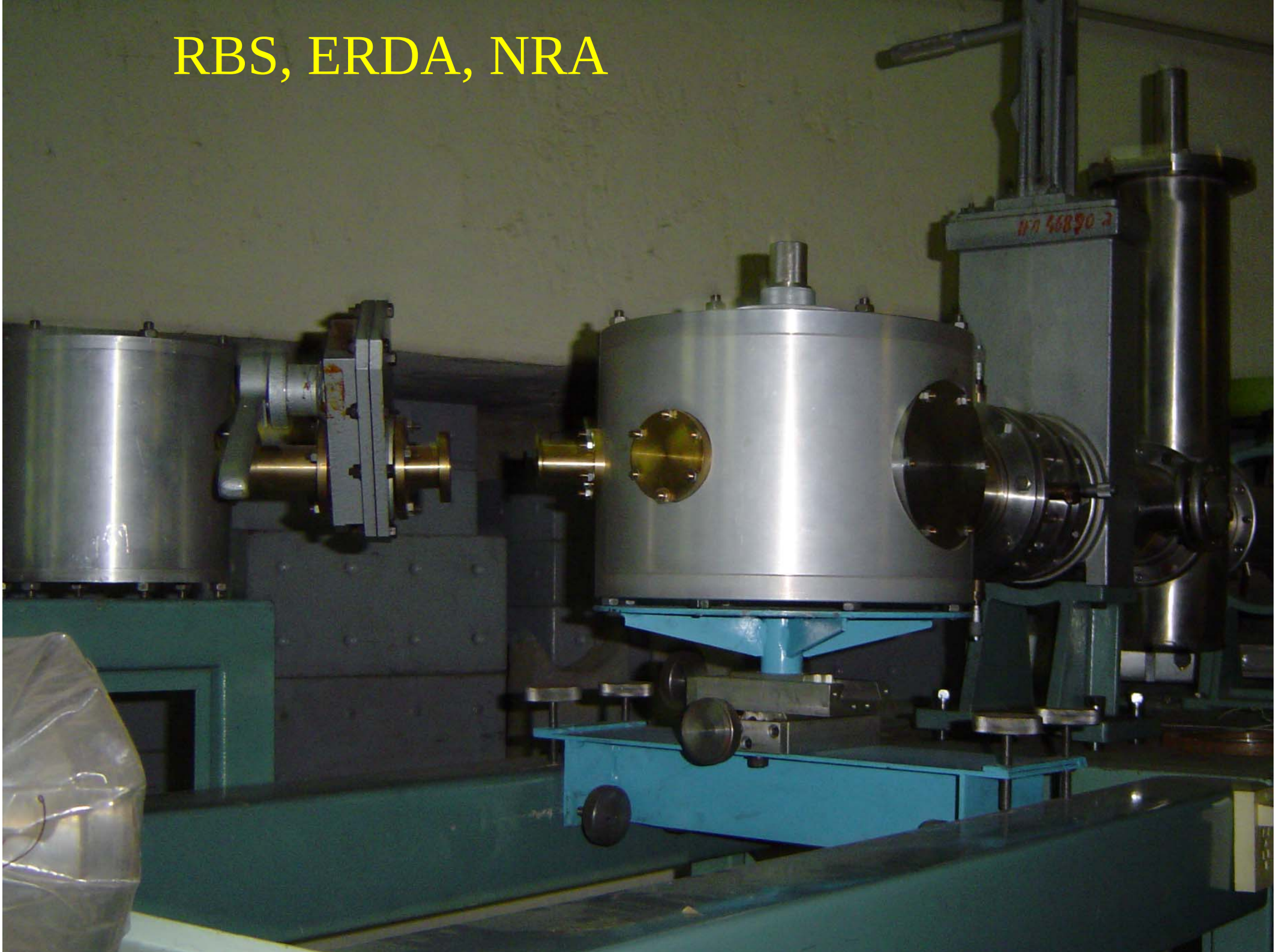
Applied Physics (~70% from the available beamtime)

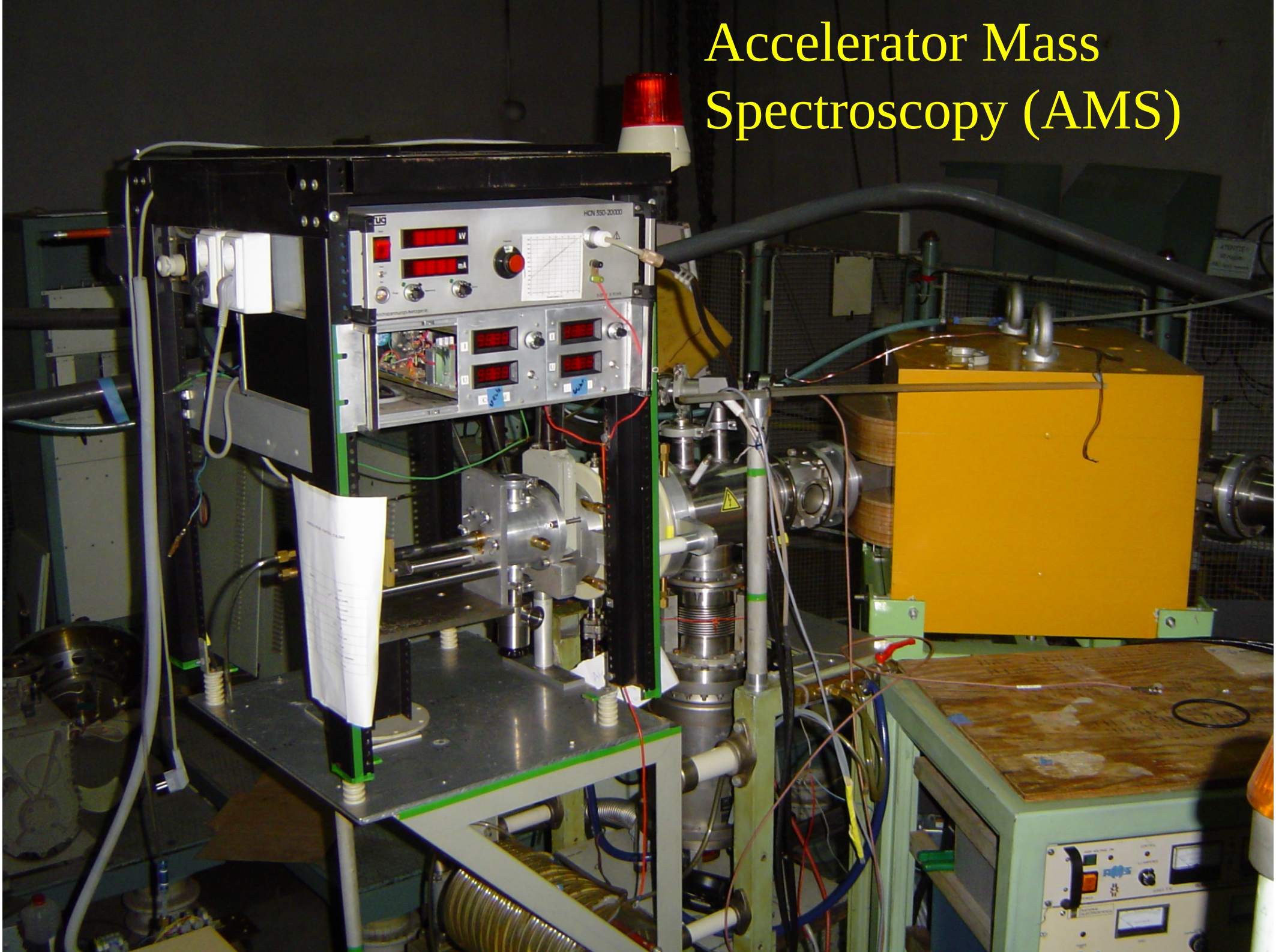
- RBS/Channeling (Rutherford back-scattering/channeling);
- NRA (Nuclear Reaction Analysis)
- ERDA (Elastic Recoil Detection Analysis)
- PIXE (Particle Induced X-Ray Emission)
- AMS (Accelerator Mass Spectrometry)

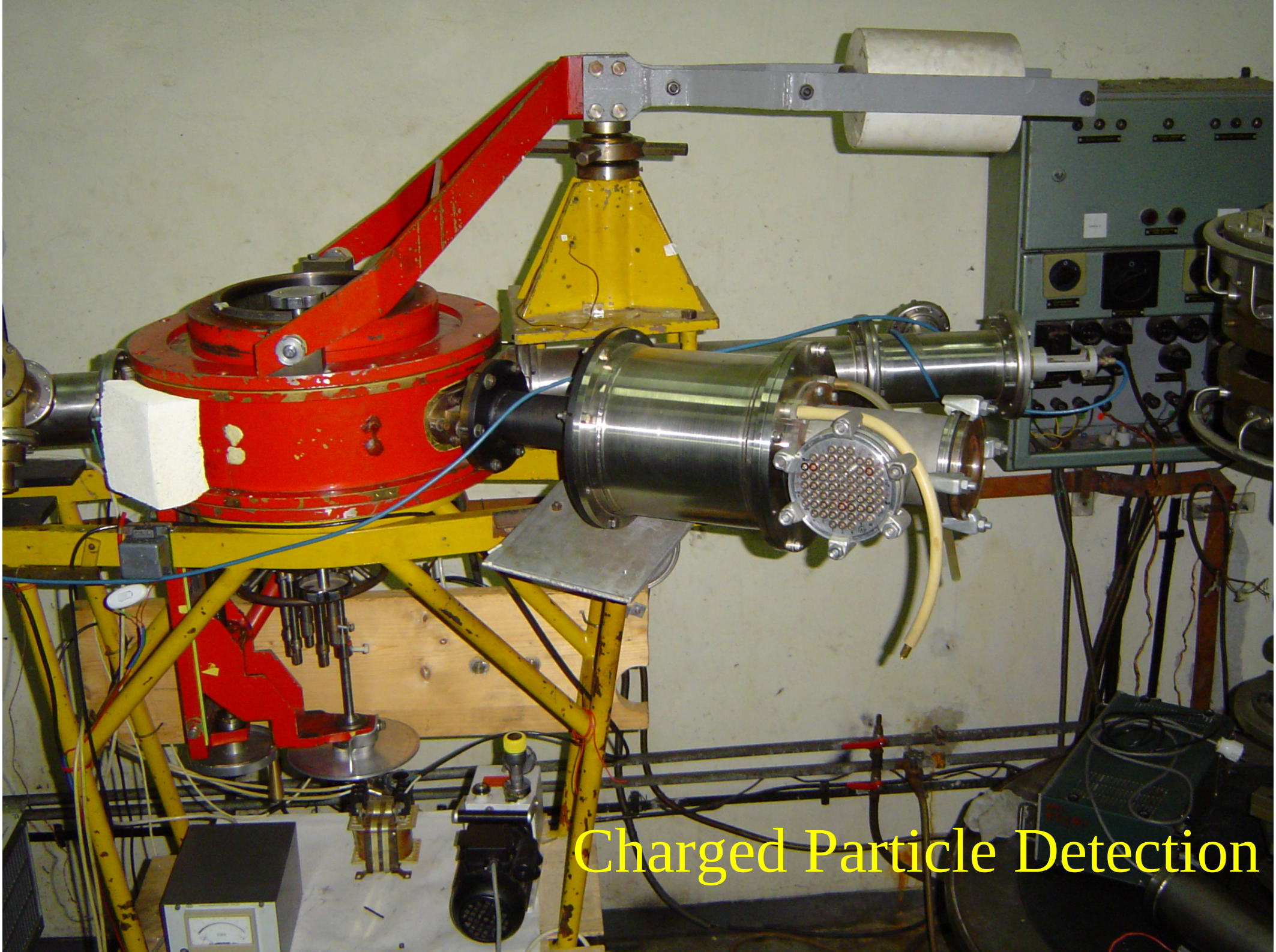
Basic research (~30% from the available beamtime)

- High spin γ-ray spectroscopy with heavy-ion fusion-evaporation reactions
- Low spin γ-ray spectroscopy with (p,n γ) reactions
- Beta decay studies
- Astrophysics

RBS, ERDA, NRA

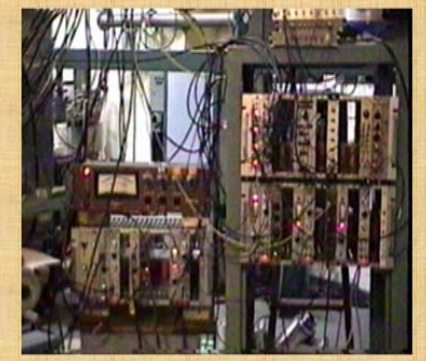



Accelerator Mass
Spectroscopy (AMS)

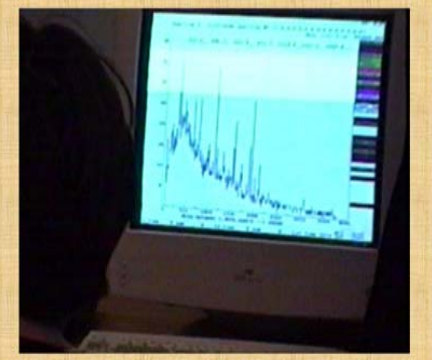

Charged Particle Detection

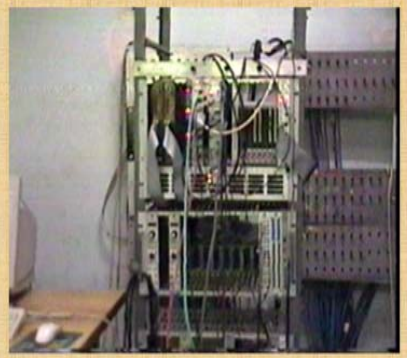
- *4 (5) HP Germanium detectors for gamma-rays*
- *1 (max. 5) detectors for neutrons*
- *1 Silicon telescope for charged particles*
- *Reaction chamber*
- *Beams of accelerated ions*

Electronics for detection and data acquisition on computer



NIM Modules



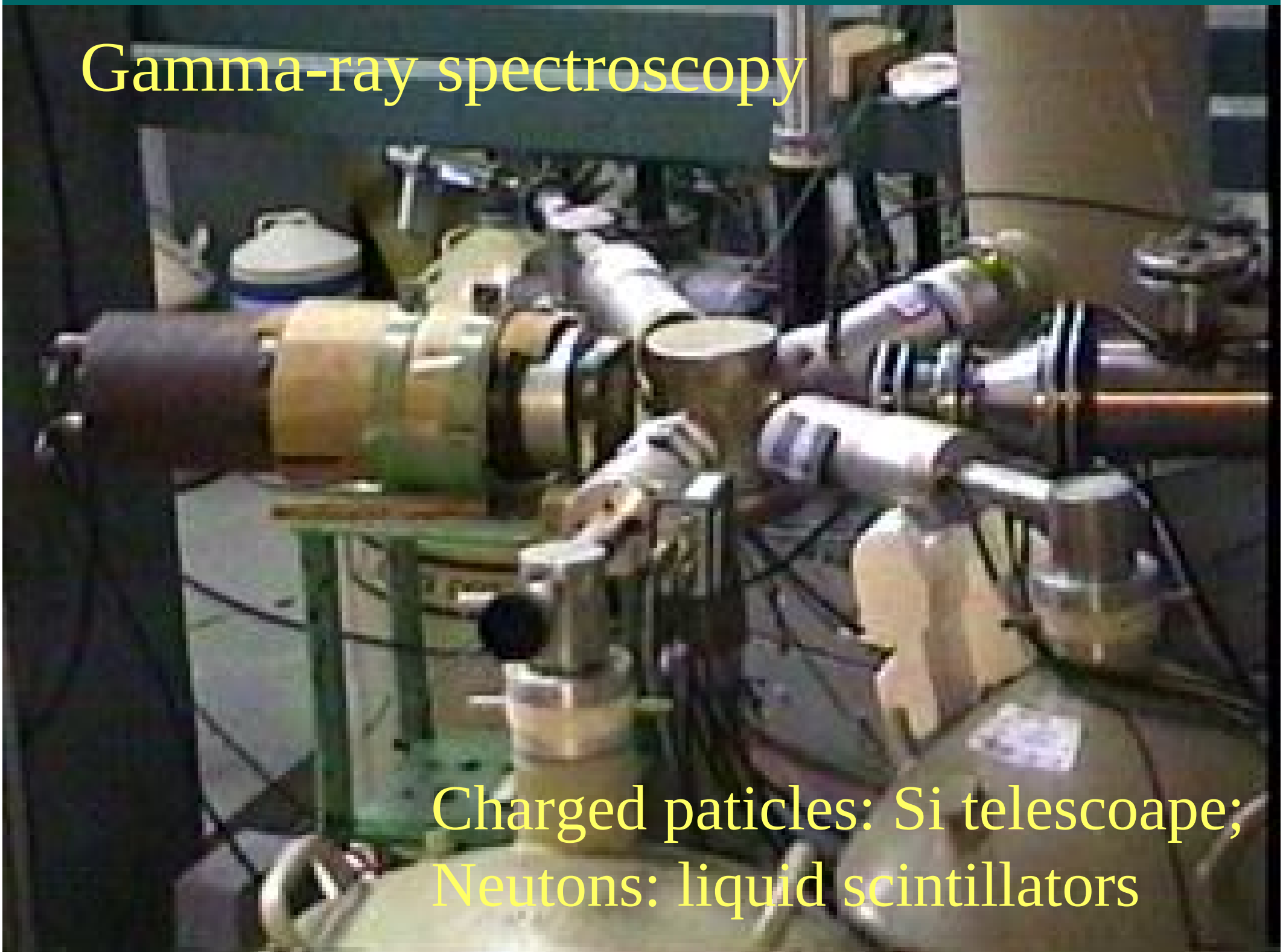


CAMAC Modules

Software for data acquisition and processing

Characteristics: *The system allows the accumulation (on hard-disk) of a list of "events" produced in the nuclear reactions produced by the bombardment of some 'target' nuclei with a beam of accelerated ions. The events are temporal coincidences of at least two of the system's detectors, and contain information on the detector number, as well as the type, energy and time of the detected radiation. After a complex analysis, the data thus*

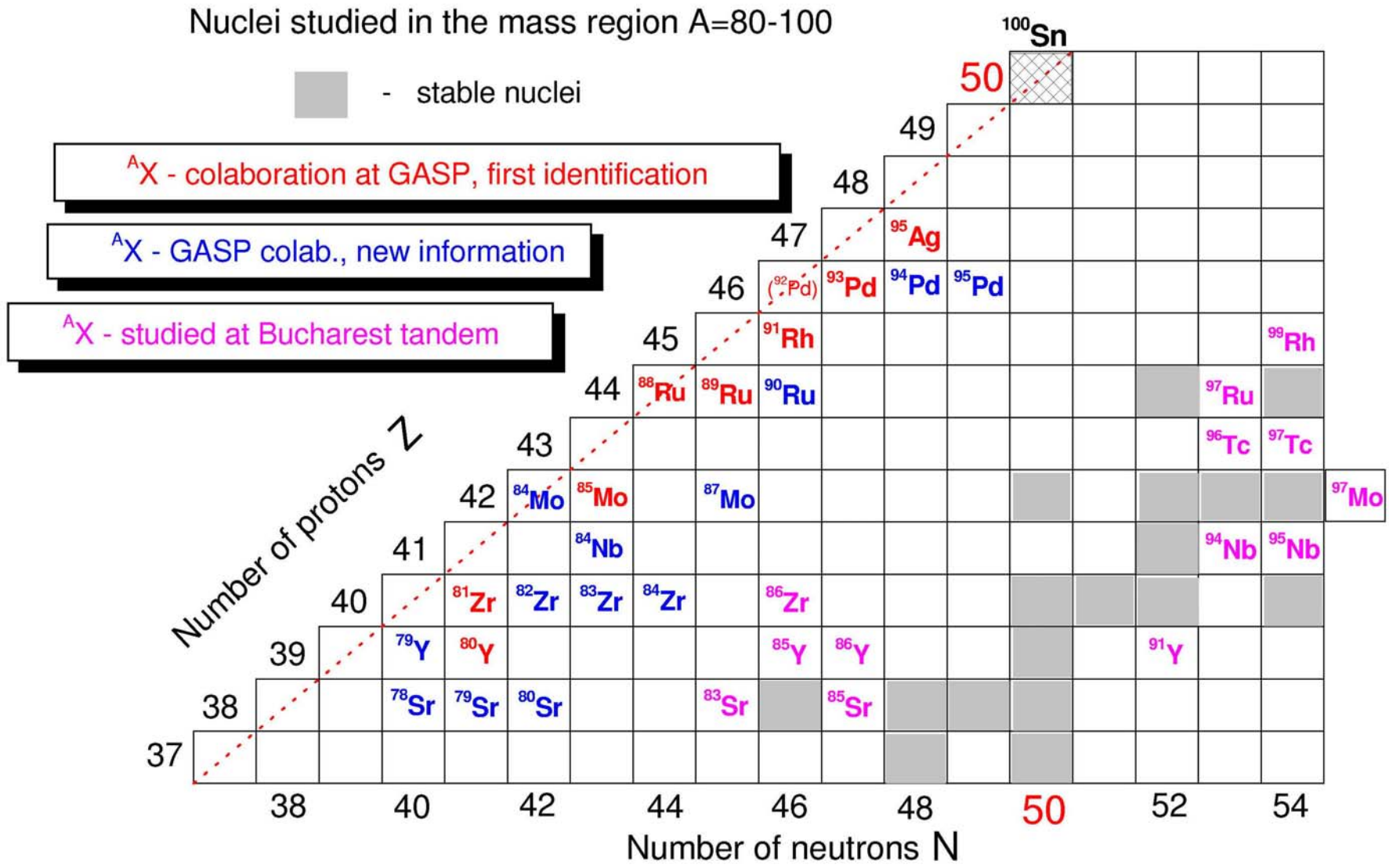
Gamma-ray spectroscopy

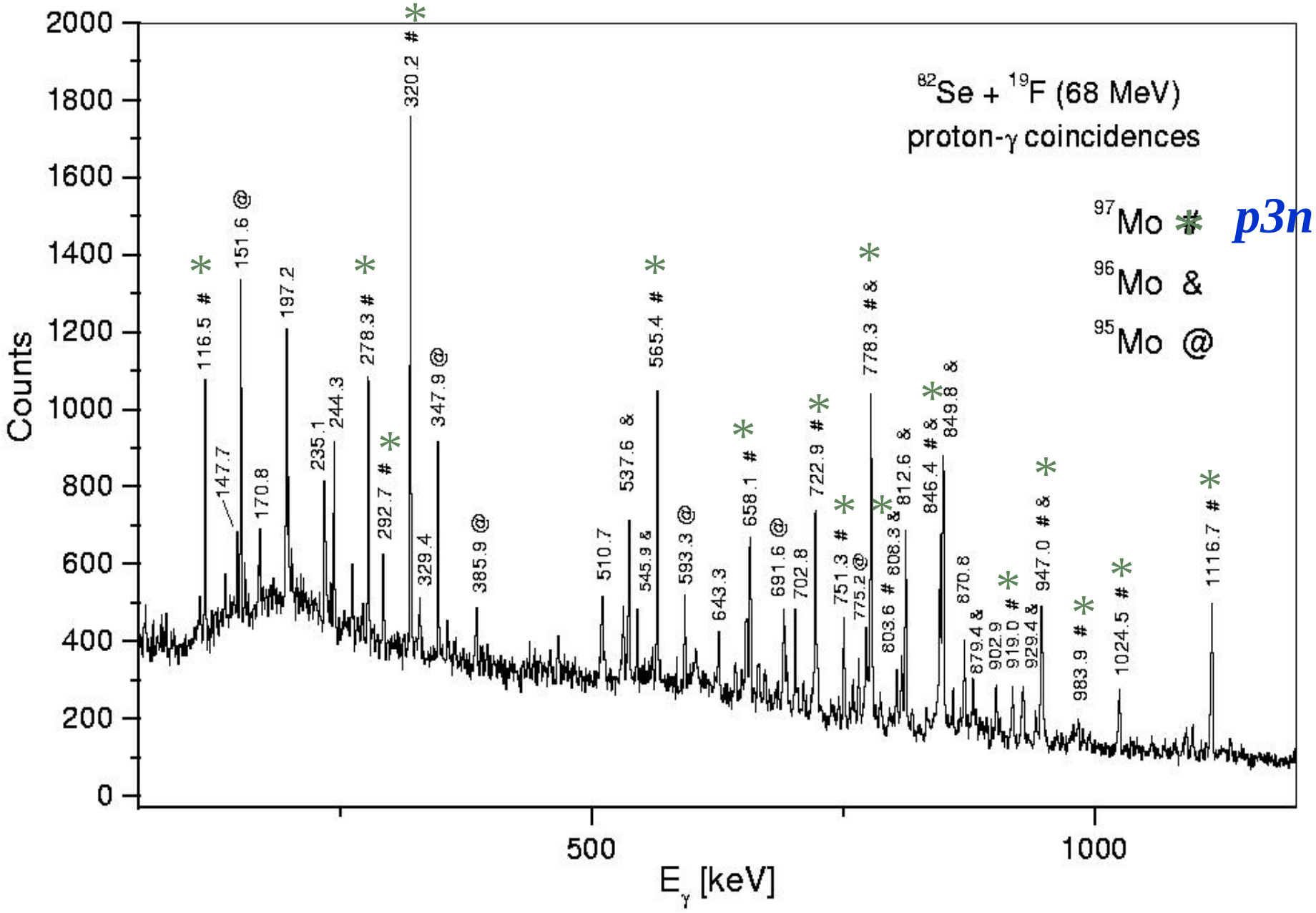


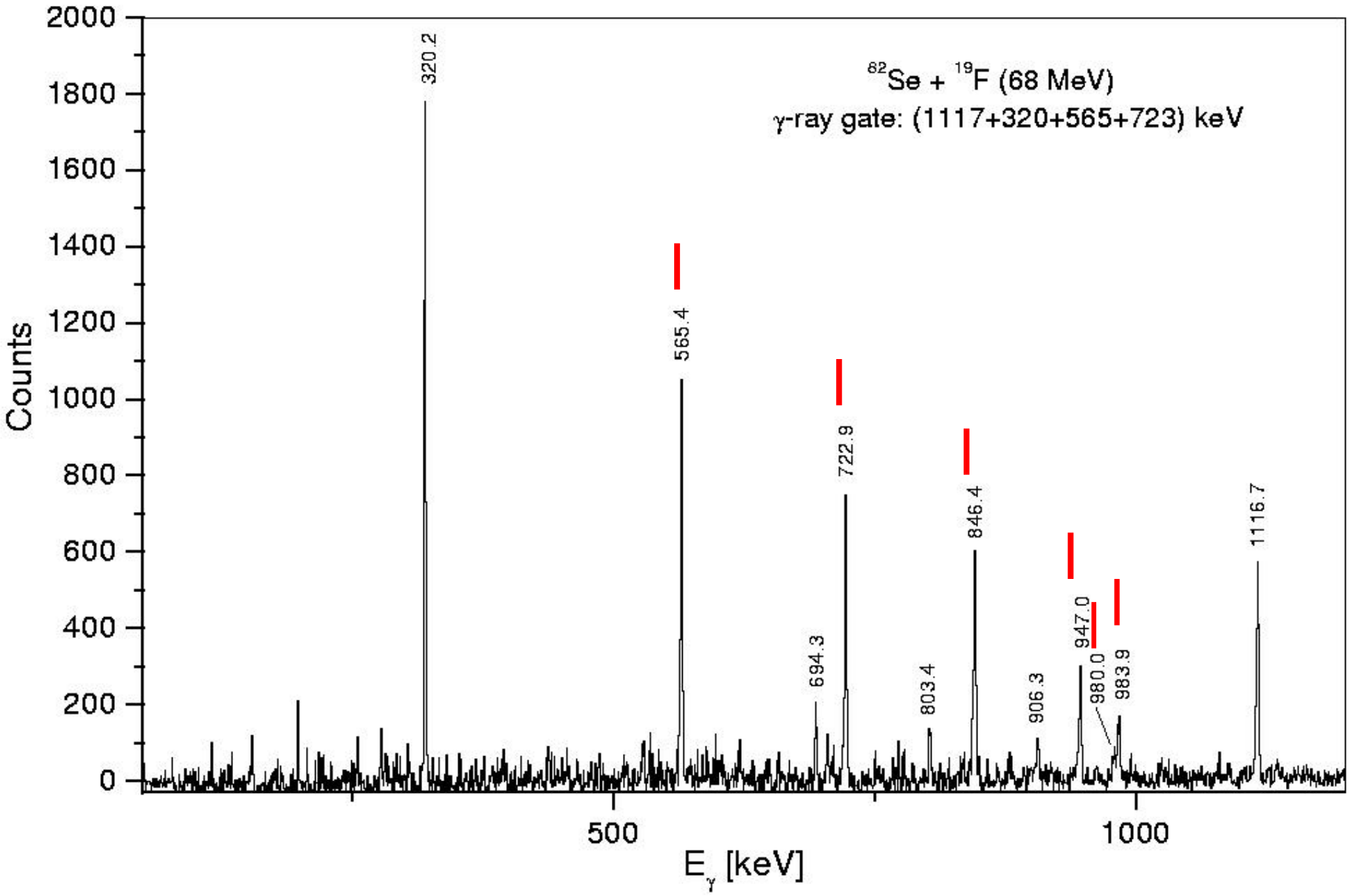
Charged paticles: Si telescoape;
Neutons: liquid scintillators

Multi-purpose gamma-array

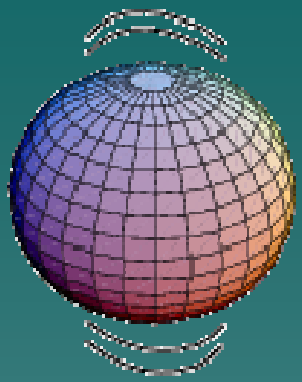
- Projects 2006
- 3 High eff. (>60%) GeHP
- Under construction
- 2007-2008 anticompton shields

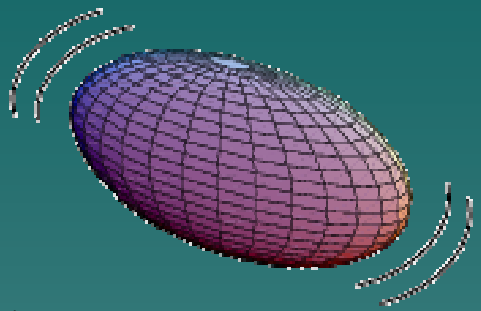

Nuclei studied in the mass region A=80-100
- stable nuclei
AX - colaboration at GASP, first identification
AX - GASP colab., new information
AX - studied at Bucharest tandem
100Sn
50
49
48
47
46
45
44
43
42
41
40
39
38
37
95Ag
(92Pd)
93Pd
94Pd
95Pd
91Rh
99Rh
88Ru
89Ru
90Ru
97Ru
96Tc
97Tc
84Mo
85Mo
87Mo
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

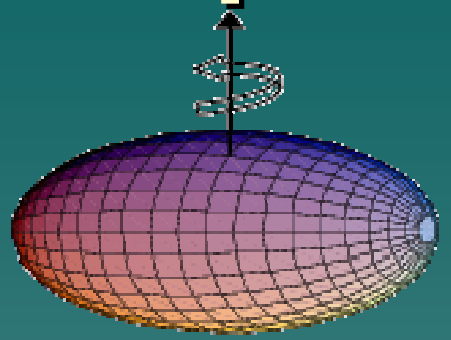

^{82}Se + ^{19}F (68 MeV)
proton-γ coincidences
^{97}Mo *
^{96}Mo &
^{95}Mo @
p3n
Counts
E$_\gamma$ [keV]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
116.5 #
147.7
151.6 @
170.8
197.2
235.1
244.3
278.3 # &
292.7 #
320.2 #
329.4
347.9 @
385.9 @
510.7
537.6 &
545.9 &
565.4 # &
593.3 @
643.3
658.1 #
691.6 @
702.8
722.9 # &
751.3 #
775.2 @
778.3 # &
803.6 #
808.3 &
812.6 &
846.4 # &
849.8 &
870.8
879.4 &
902.9
919.0 #
929.4 &
947.0 # &
983.9 #
1024.5 #
1116.7 #

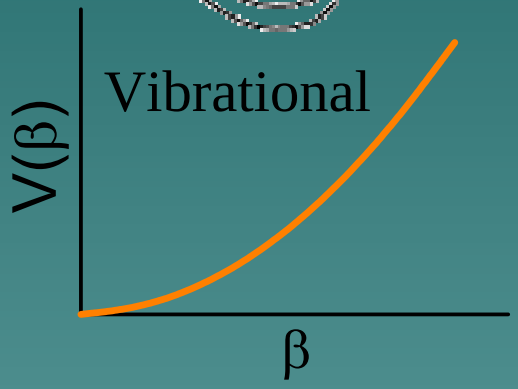

^{82}Se + ^{19}F (68 MeV)
γ-ray gate: (1117+320+565+723) keV
Counts
E_γ [keV]
320.2
565.4
694.3
722.9
803.4
846.4
906.3
947.0
980.0
983.9
1116.7
0
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000

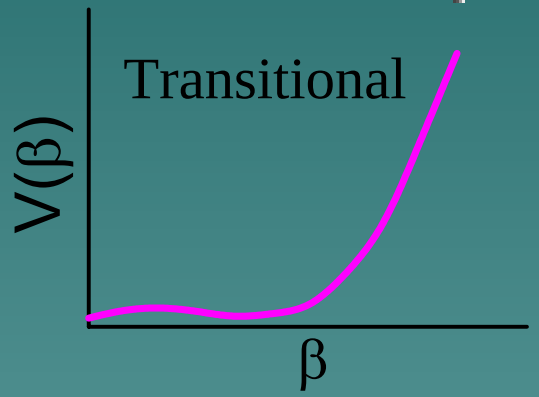
Evolution of Nuclear Shape

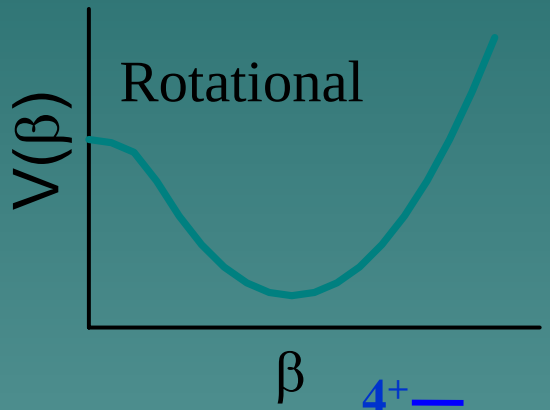


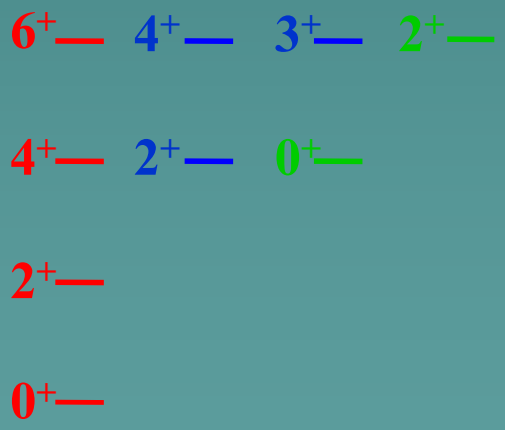




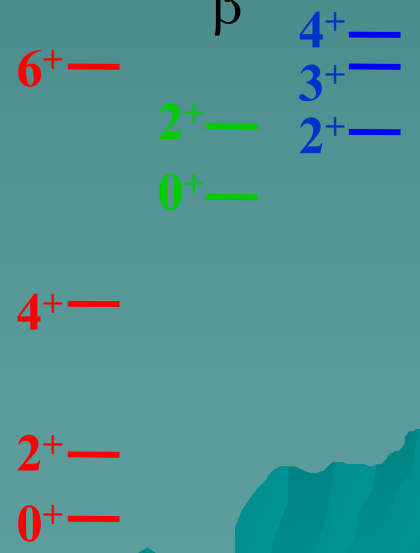








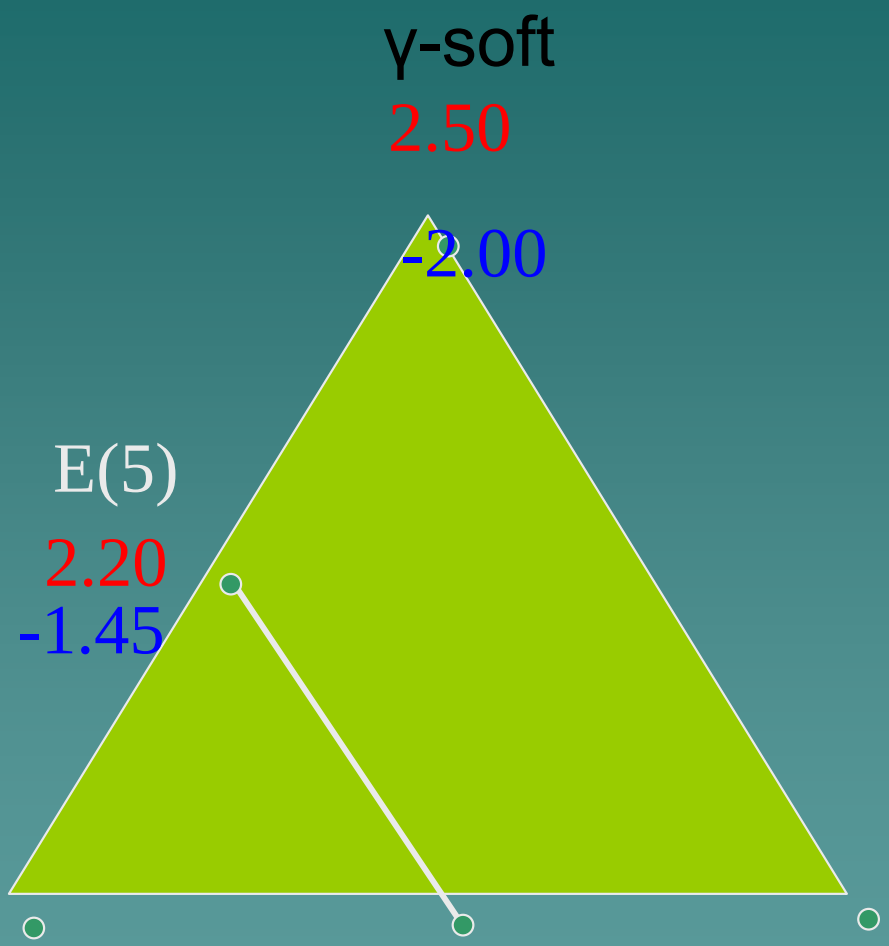
Critical Point Symmetries
X(5), E(5)



$E \sim n\hbar\omega$

$E \sim J(J+1)$

Casten Triangle

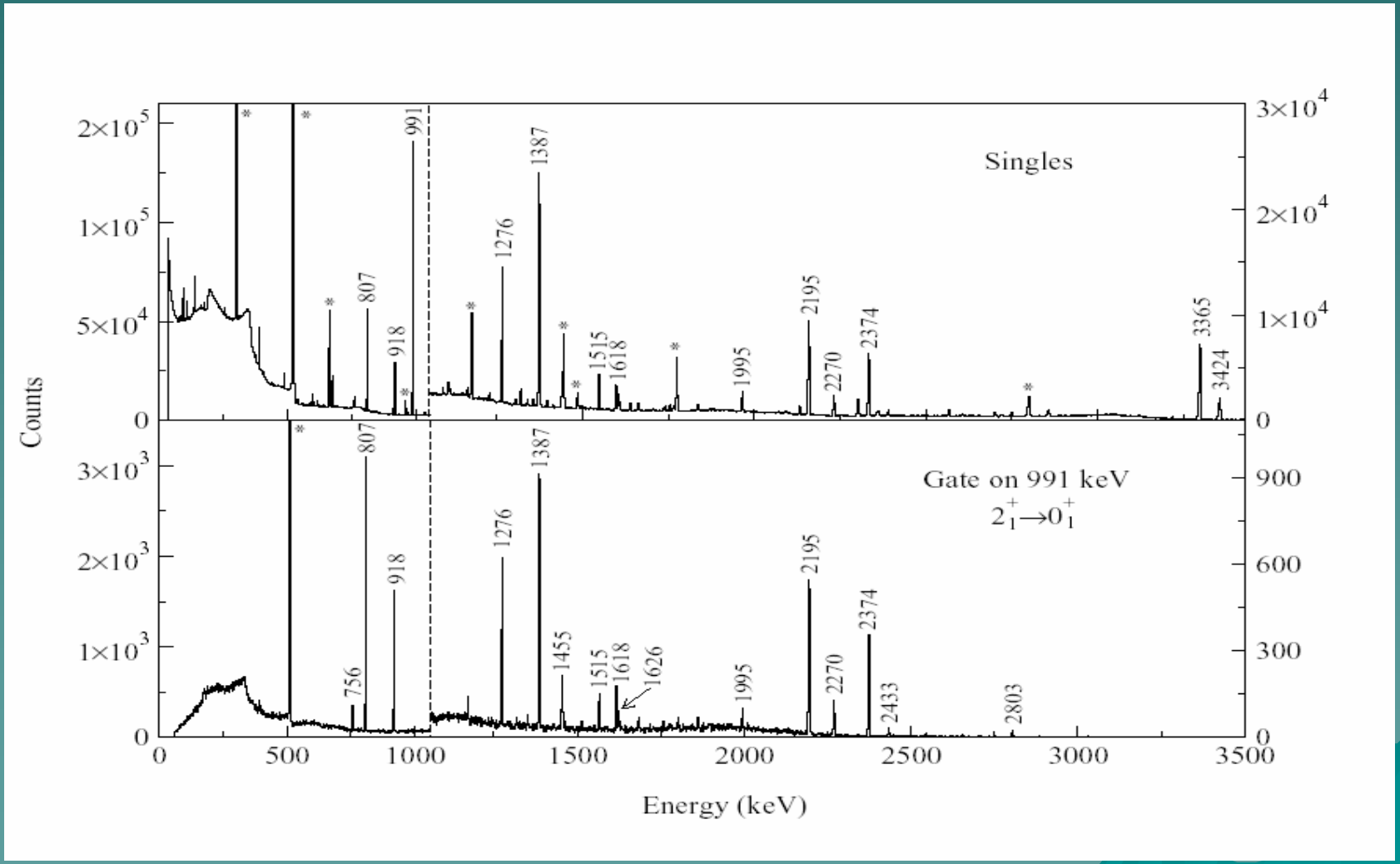


$$^{54}Fe(^{12}C, pn)^{64}Ga \xrightarrow{\varepsilon / \beta^+} {}^{64}Zn$$

$T_{1/2}$=158 s

^{12}C: 36 MeV,3 pnA, t=250 s, ^{54}Fe: 13mg/cm^2, 99%

3HPGe detectors 20% eff.



Specific Infos required in the frame of dLSF initiative (1)

1. SCIENTIFIC MISSION

The mission of the facilities is to carry out competitive basic and applied scientific research based on accelerated ion beams and to provide training opportunities for undergraduate and PhD students, in collaboration with Romanian Universities.

The current research programme encompasses Nuclear Structure Physics, Atomic Physics, Interdisciplinary research on Material Sciences, Biology, Medicine and Ecology.

In the future, a large fraction of the research Programs will be allocated also to the studies based on Accelerator Mass Spectrometry (AMS) techniques and those required in Nuclear Astrophysics.

Specific Infos required in the frame of dLSF initiative (2)

2. BRIEF CHARACTERISE THE FACILITY

Electrostatic Tandem Accelerator operating at voltages up to 9 MV with light and heavy ions.
Continous and chopped beams ; 3 ion sources
(one Duoplasmatron and two Sputtering Hiconex 834);
Gas and foil stripping; 7 experimental beamlines.

Electronic Cyclotron Resonance Ion Source,
Microwave frequency: 14.5 GHz;
Mirror field strength, injection/middle/extraction: 1.2 / 0.34 / 1 T ;
Hexapole permanent magnet: Halbach structure, 24 radial segments ;
plasma chamber: 5. cm diameter X (15-25) cm length (variable):
platform voltage: 2 – 50 kV.

Specific Infos required in the frame of dLSF initiative (3)

1. Tandem Accelerator: currently accelerated Beams

Beam Species	Max Energy [MeV]	Intensity on target [nA]	Obervations
Protons	16	700	duoplasmatron
Deuterons	16	500	duoplasmatron
^{4}He	24	20	A new, dedicated source under development
^{7}Li	32	10	sputtering
^{9}Be	32	7	sputtering
^{10}B	48	5	sputtering
^{11}B	48	9	sputtering
^{12}C	56	100	duoplasmatron
^{14}N	64	30	duoplasmatron
^{16}O	56	400	duoplasmatron
^{19}F	72	15	duoplasmatron
^{24}Mg	56	50	sputtering
^{28}Si	48	30	sputtering
^{32}S	82	100	sputtering
^{35}Cl	42	25	sputtering
^{48}Ti	64	1	sputtering
^{52}Cr	96	1.1	sputtering
^{56}Fe	84	1.5	sputtering
^{58}Ni	88	2.7	sputtering
^{59}Co	96	0.8	sputtering
^{63}Cu	88	1.6	sputtering
^{79}Br	91	0.9	sputtering
^{81}Br	84	1.1	sputtering
^{127}I	88	0.7	sputtering
^{198}Au	96	1	sputtering

ECR Ion Source : Beams under development ; tested: H, N, O, Ar.

Specific Infos required in the frame of dLSF initiative (4)

4. EXPERIMENTAL INSTRUMENTATION
Gamma rays detectors (5 GeHP and 7 NaI(Tl) scintillators);
neutron liquid scintillators, X-rays detectors (Si(Li)) , charged particles detectors (Si), several reaction chambers. Comercial electronic modules in NIM and CAMMAC standards. Data Acquisition System based on CAMMAC modules.
Local Area Computer Network with fast INTERNET access.

5. It is a User Facility – recognized officially by the National Agency for Scientific Research and an appropriate Funding for maintenance and operation is provided.

6. The Facility has no official PAC. Allocation of he Accelerator time is through an internal committee.

7. The two-year average for the period 2004-2005 is 47 users per year.

Specific Infos required in the frame of dLSF initiative (5)

Beamtime distribution (about 3500 hours/year)

- (2004-2005): 93% (national users)
- (2002-2005): 97% (national users)
- (2002-2005): 3% (outside the country)
- (2004-2005): 1% (North-America)

Beamtime requests can be formulated by accessing the web page
http://tandem.nipne.ro/resources_index.html

European Centre of Excellence ``InterDisciplinary Research and Applications based on Nuclear and Atomic Physics'' IDRANAP

- Nuclear methods for studying environmental pollution components
- Applications of nuclear physics methods in biology and medicine
- Radionuclide metrology
- Nuclear physics method for materials characterization
- Nuclei far from stability, decay modes, cosmic rays and facilities

European Collaborations

- Collborations with 14 Labs and Universities
- ***EURONS***:
  - * **AGATA** (Advanced Gamma Tracking Array)
  - * **EXOCHAP** (Improvement of charged particle and fragment detectors)
  - * **ISIBHI** (New ECR Ion Sources)
  - * **SEENET** (South-East European Network)
- ***EURISOL***
- ***EURATOM:*** Gamma and high-energy proton irradiation of optical transmission materials, High sensitivity measurement of Hydrogen isotopes in Tokamak projects
- Member of JINR-Dubna, FAIR

International Facility for Antiproton and Ion Research (FAIR) at Darmstadt

Duration: 2007 – 2014

Costs: ~1.3 billion €, 25% from international partners

Members: China, Finland, France, Germany, Greece, India, Italy, Poland, Romania, Russia, Spain, Sweden, UK

IFIN-HH:

- Nuclear Structure & Astrophysics with Radioactive Beams (NUSTAR)
- Stored Particles Atomic Physics Research (SPARC)
- Compressed Baryonic Matter (CBM)
- Antiproton Annihilation at Darmstadt (PANDA)

Conclusions

- The Bucharest Tandem Accelerator *"Small Scale Facility part of the European Infrastructure"*

- Complementary to Large Scale European Facilities:

- More "classical" directions, which can still lead to important contributions to the field

- Ideal places for educating young scientists; they go through all stages of an experiment and really achieve the desirable skills needed for future LSF groups

- An apropriate place for developing instruments or experimental methods intended for a LSF

- A correct balance between participating at experiments at LSF and developing an "in house" scientific program