Gamma Ray Spectroscopy of ^{34}Ar Using Fusion Evaporation

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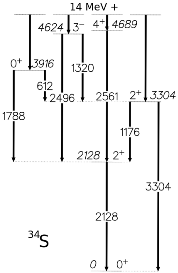
Mirror Nuclei

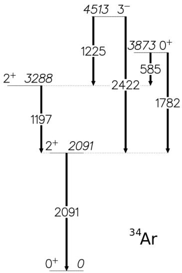
Mirror nuclei are defined by a switch of proton and neutron numbers in a nuclide

$$T_z = 1 \ \rightarrow T_z = -1$$

$$^{34}_{16}S_{18} \rightarrow {}^{34}_{18}Ar_{16}$$

Doing this allows us to observe isospin symmetry directly

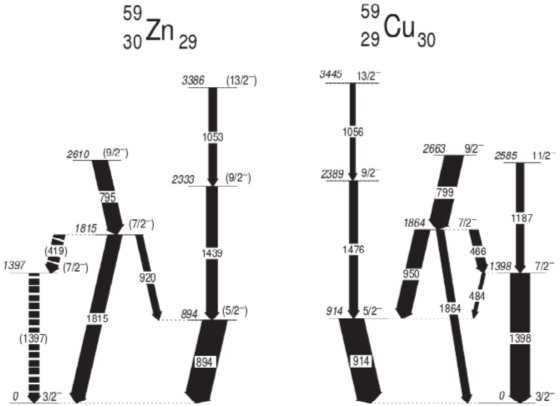




Symmetric Mirror Nuclei

Theory predicts mirror nuclei to behave the same:

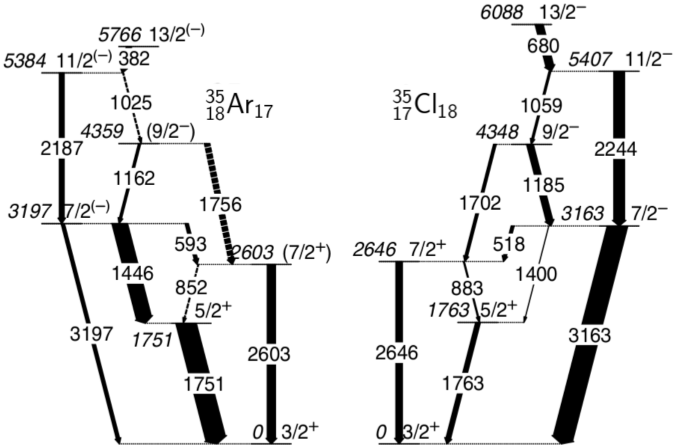
- Energy levels are similar
- Relative intensity of transitions fairly similar



C. Andeoiu et al., Eur. Phys. J. A **15**, 459-462 (2002).

Asymmetric Mirror Nuclei

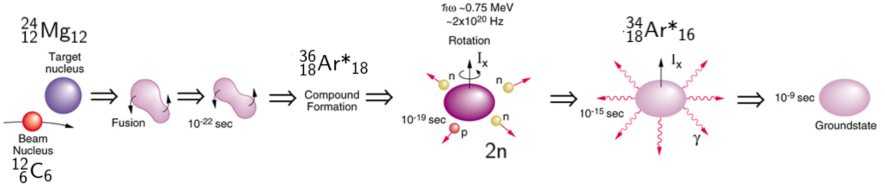
- Differences in energy and intensity possible
- Predictions of theory start breaking down



J. Ekman et al.,Phys. Rev. Lett. **92**, 132502 (2004).

Fusion Evaporation

35 MeV ^{12}C beam on ^{24}Mg target (0.5 mg/cm^2)



2n channel and ^{34}Ar nucleus shown as an example above. Many other nuclei are produced.

Using PACE4 to simulate the fusion evaporation experiment:

Select Products of Reaction

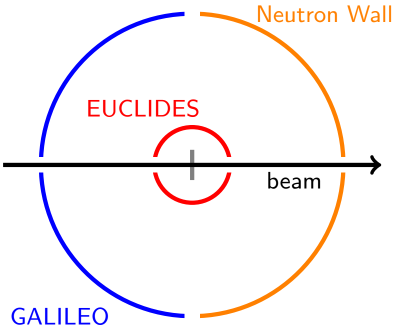
Product	**Cross-section (mb)**	**% of Simulated Events**
⋮	⋮	⋮
^{34}Ar	0.287	0.03
^{34}Cl	133	13.9
^{34}S	92.3	9.65
⋮	⋮	⋮
^{31}P	481	50.3
⋮	⋮	⋮

Equipment

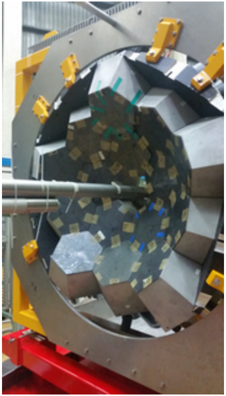
Experiment was conducted at the **Laboratori Nazionali di Legnaro (LNL) – Istituto Nazionale di Fisica Nucleare (INFN)**

Detector Arrays

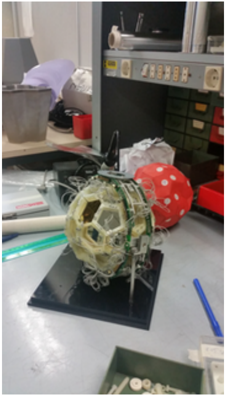
- **EUCLIDES** – charged particles
- **GALILEO** – γ-rays
- **Neutron Wall** – neutrons



GALILEO consist of 24 HPGe detectors



Neutron wall has 15 liquid scintillators and a smaller pentagonal central unit

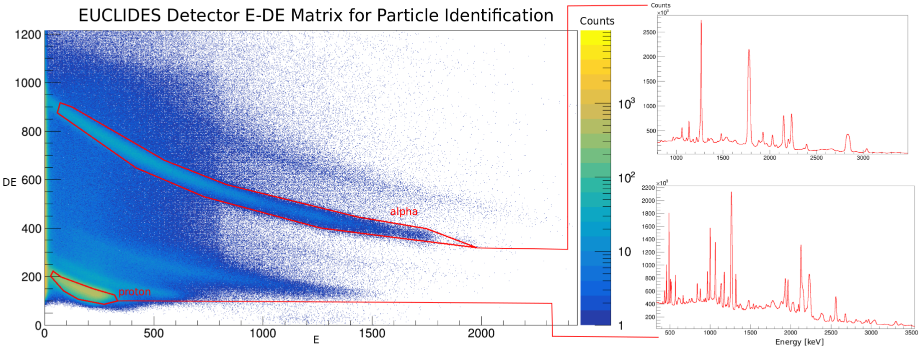


EUCLIDES ball of 38 E-DE Si telescopes

Courtesy F.H. Garcia

EUCLIDES Charged Particle Identification

Associating γ-ray coincidences with charged particle events



Doppler Corrections

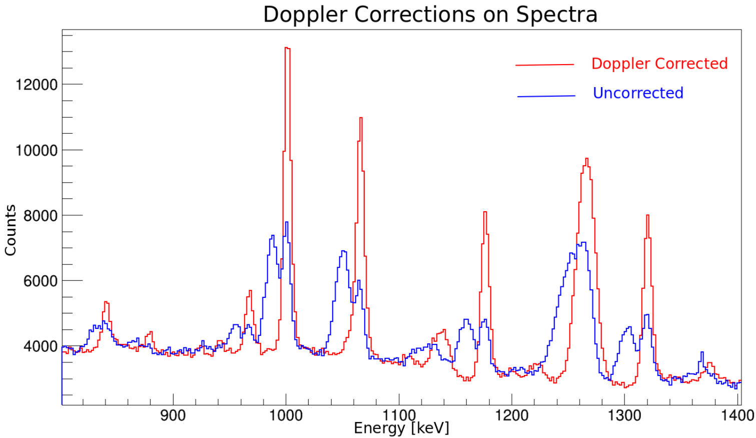
Particles in flight result in **Doppler shift** of γ-rays.

$$E_{observed} = E_\gamma \frac{\sqrt{1-\beta^2}}{1-\beta\cos\theta}; \qquad \beta = \frac{v_d}{c}$$

- Peak broadening effects
- Event-by-event reconstructions possible for EUCLIDES data

Notable Features

- Multiple peaks
- Peaks shift in energy
- Blurring and widening of some peaks



Building a Level Scheme

Projection around 2561 keV for ^{34}S

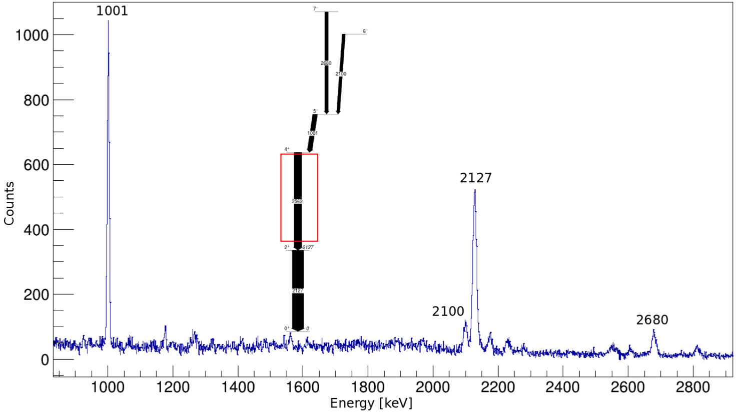
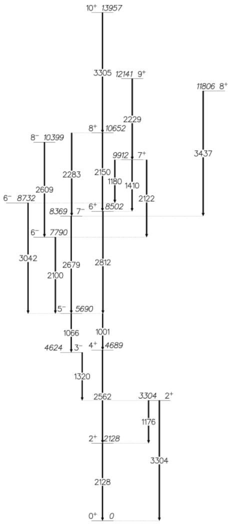
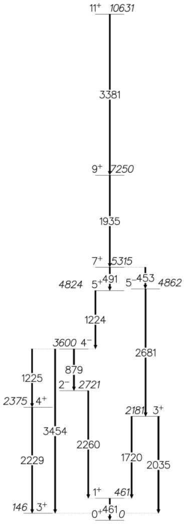


Figure: A spectrum from the $2p$ channel gated on the 2561 keV transition

Verifying Energy Levels



Level scheme of ^{34}S observed



Level scheme of ^{34}Cl observed

- ^{34}S energy levels observed match levels listed in NNDC up to 14 MeV
- ^{34}Cl energy levels observed to 10 MeV
- ^{34}Ar needs more statistics

Summary and Future Work

- Validate Doppler corrections with known nuclei
- Examine 2n channel for ^{34}Ar

Acknowledgements

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NSERC CRSNG

INFN Istituto Nazionale di Fisica Nucleare

Laboratori Nazionali di Legnaro

Full List of Cross-sections

^{36}Ar Compound Nucleus

1.Yields of residual nuclei

Z	N	A	events	percent	x-section (mb)
18	17	35 Ar	49	0.49%	4.68
17	18	35 Cl	61	0.61%	5.83
18	16	34 Ar	3	0.03%	0.287
17	17	34 Cl	1390	13.9%	133
16	18	34 S	965	9.65%	92.3
17	16	33 Cl	1	0.01%	0.0956
16	17	33 S	585	5.85%	55.9
15	18	33 P	35	0.35%	3.35
16	16	32 S	377	3.77%	36
16	15	31 S	333	3.33%	31.8
15	16	31 P	5032	50.3%	481
15	15	30 P	9	0.09%	0.86
14	16	30 Si	2	0.02%	0.191
14	14	28 Si	1113	11.1%	106
13	14	27 Al	45	0.45%	4.3
TOTAL			10000	100%	956

^{28}Si Compound Nucleus

Z	N	A	events	percent	x-section (mb)
14	14	28 Si	122	0.122%	1.22
14	13	27 Si	6484	6.48%	65.1
13	14	27 Al	18335	18.3%	184
13	13	26 Al	16784	16.8%	168
12	14	26 Mg	2743	2.74%	27.5
12	13	25 Mg	22	0.022%	0.221
12	12	24 Mg	11523	11.5%	116
12	11	23 Mg	1054	1.05%	10.6
11	12	23 Na	34651	34.7%	348
10	10	20 Ne	8282	8.28%	83.1
TOTAL			100000	100%	1e+03

Example of Kinematic Reconstruction