In-beam γ-ray spectroscopy of ^{94}Ag

X. Pereira-López

Center for Exotic Nuclear Studies, Institute for Basic Science (IBS)
University of York

CENS
CENTER FOR EXOTIC NUCLEAR STUDIES

UNIVERSITY of York

Contents

- Motivation
    - Isospin-symmetry
        - MED
        - TED
        - CED
    - Nucleon pairing
- Experimental setup
- Results
- Discussion
- Conclusions

Isospin

Observation of similar behaviour of p and n under the nuclear force

- Charge independence $$V_{np} = \frac{V_{pp} + V_{nn}}{2}$$
- Charge symmetry $$V_{pp} = V_{nn}$$

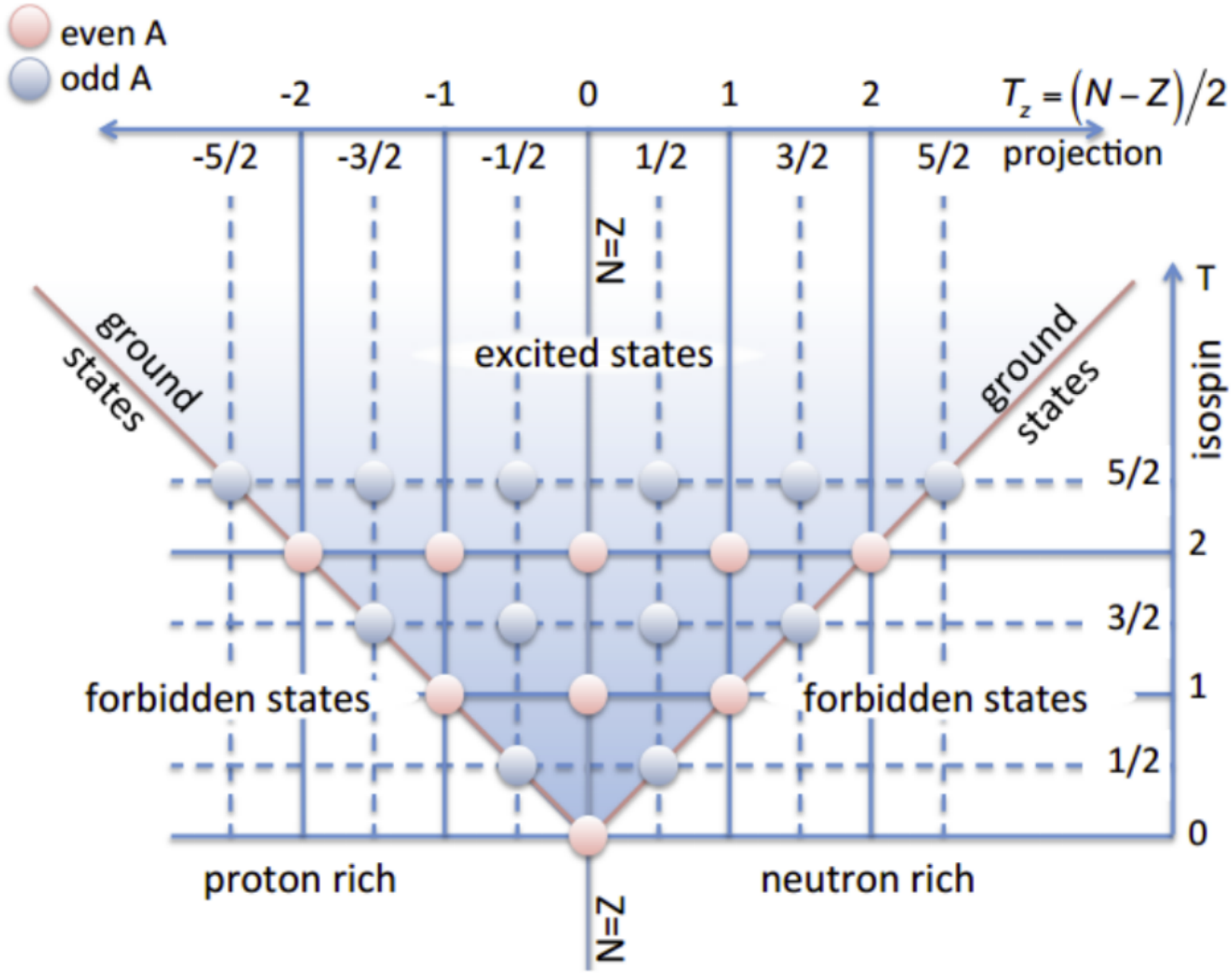
Isospin: p and n considered states of the same particle (*nucleon*) with different projections of the isospin quantum number t_z. The total isospin projection T_z of a nucleus will be:

$$T_z = \sum^{A} t_z = \frac{N - Z}{2}$$

Hence, a nucleus can occupy states with a total isospin T values given by:

$$\frac{|N - Z|}{2} \leqslant T \leqslant \frac{|N + Z|}{2}$$

Isospin

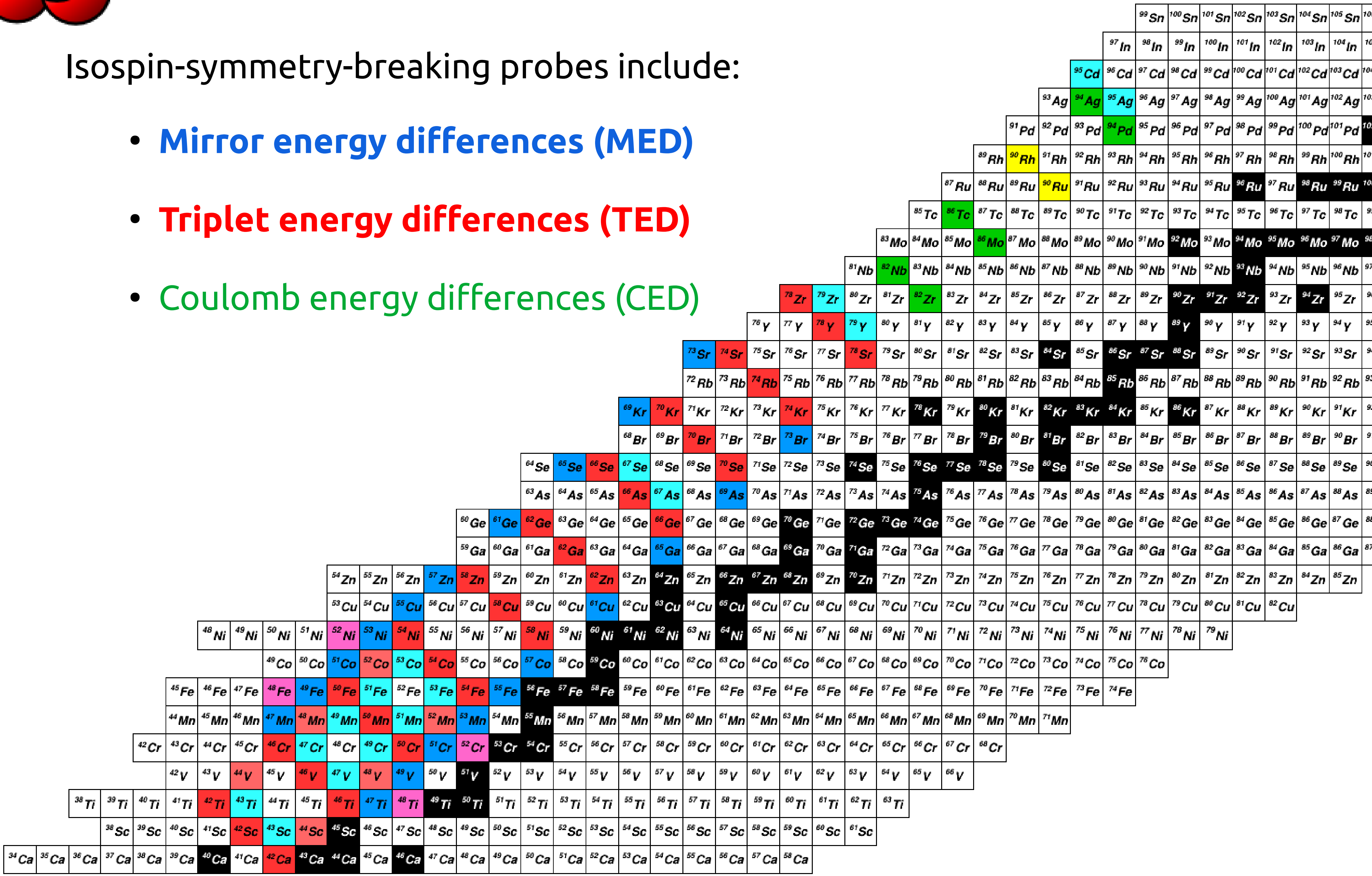


Bentley Isospin triangle displaying possible T states for a nucleus with a given T_z

Isospin symmetry

Isospin-symmetry-breaking probes include:

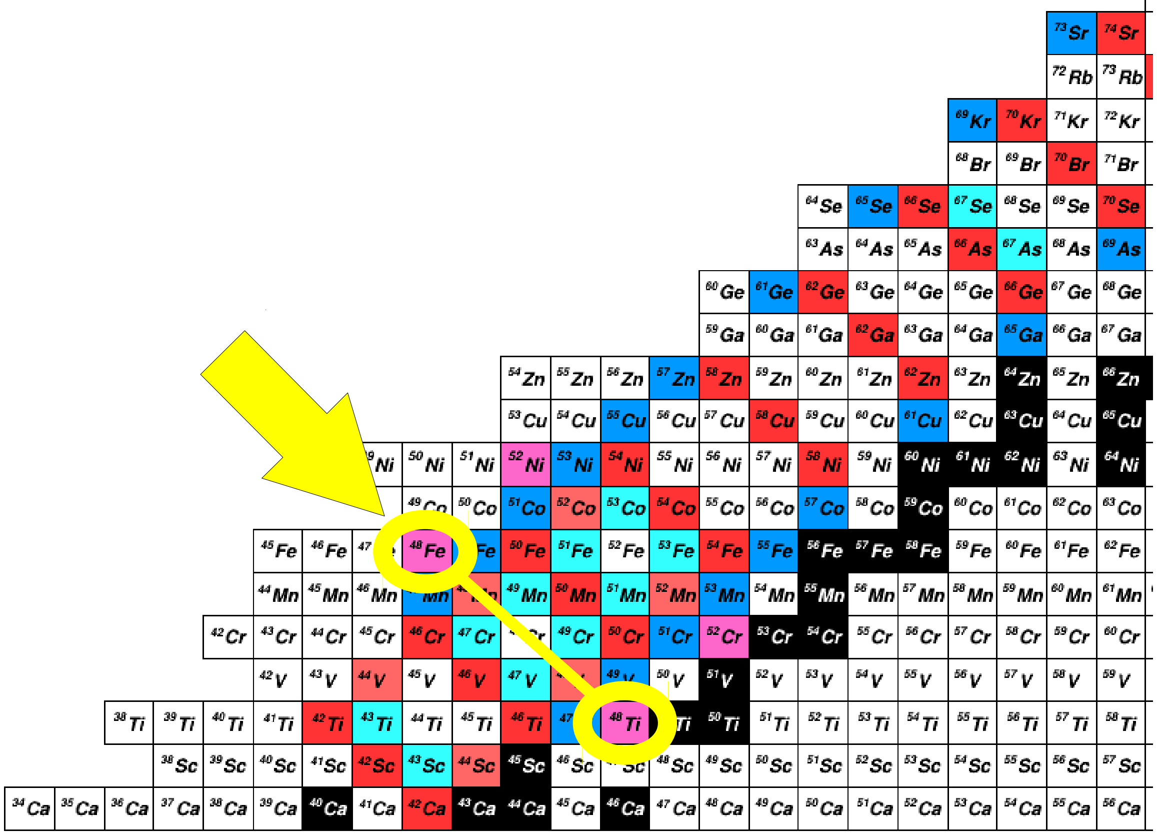
- **Mirror energy differences (MED)**
- **Triplet energy differences (TED)**
- Coulomb energy differences (CED)

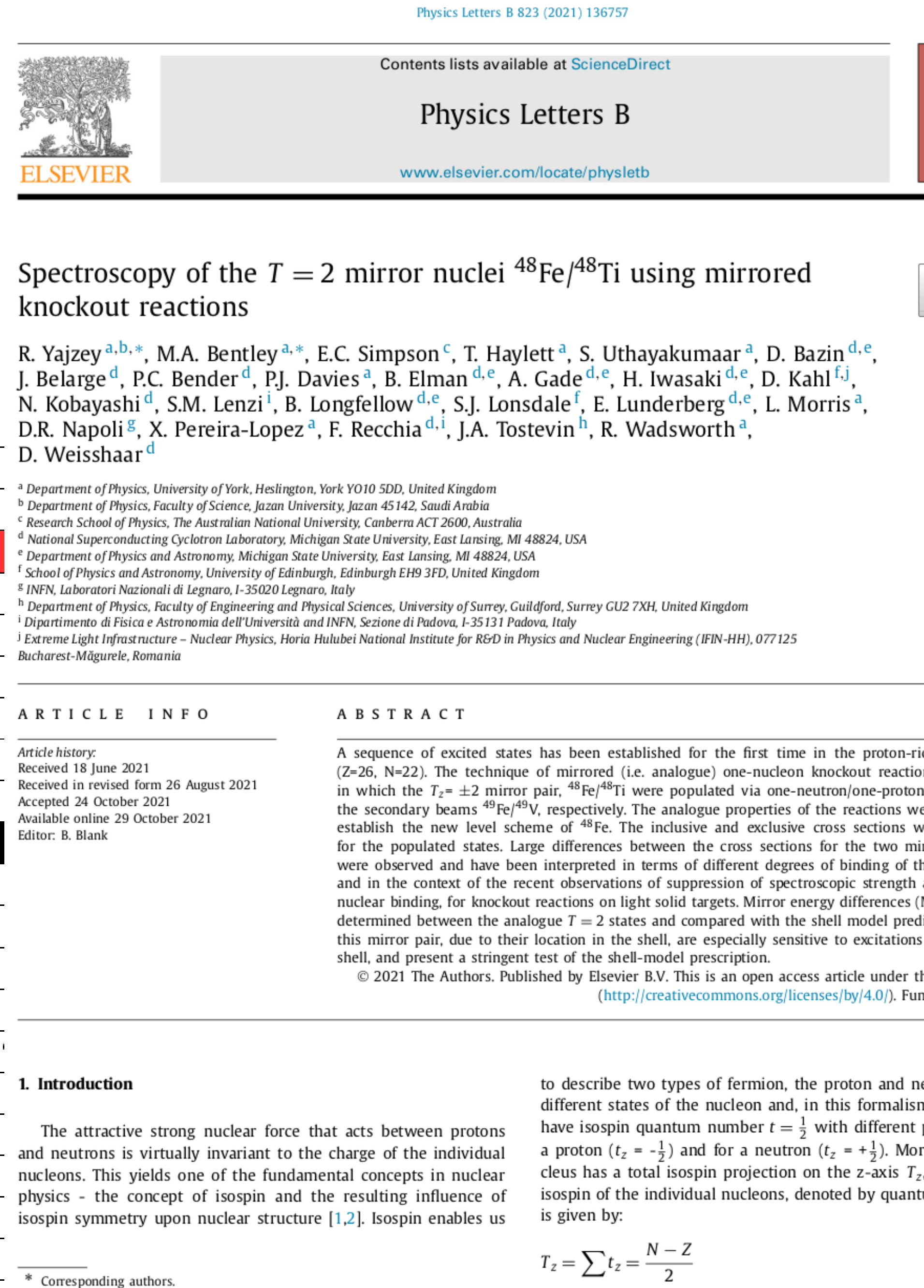


Isospin symmetry

Isospin-symmetry-breaking probes include:

- **Mirror energy differences (MED)**
- **Triplet energy differences (TED)**
- Coulomb energy differences (CED)





Physics Letters B 823 (2021) 136757

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Spectroscopy of the $T = 2$ mirror nuclei ^{48}Fe/^{48}Ti using mirrored knockout reactions

R. Yajzey [a,b,*], M.A. Bentley [a,*], E.C. Simpson [c], T. Haylett [a], S. Uthayakumaar [a], D. Bazin [d,e], J. Belarge [d], P.C. Bender [d], P.J. Davies [a], B. Elman [d,e], A. Gade [d,e], H. Iwasaki [d,e], D. Kahl [f,j], N. Kobayashi [d], S.M. Lenzi [i], B. Longfellow [d,e], S.J. Lonsdale [f], E. Lunderberg [d,e], L. Morris [a], D.R. Napoli [g], X. Pereira-Lopez [a], F. Recchia [d,i], J.A. Tostevin [h], R. Wadsworth [a], D. Weisshaar [d]

[a] Department of Physics, University of York, Heslington, York YO10 5DD, United Kingdom
[b] Department of Physics, Faculty of Science, Jazan University, Jazan 45142, Saudi Arabia
[c] Research School of Physics, The Australian National University, Canberra ACT 2600, Australia
[d] National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, MI 48824, USA
[e] Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA
[f] School of Physics and Astronomy, University of Edinburgh, Edinburgh EH9 3FD, United Kingdom
[g] INFN, Laboratori Nazionali di Legnaro, I-35020 Legnaro, Italy
[h] Department of Physics, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, Surrey GU2 7XH, United Kingdom
[i] Dipartimento di Fisica e Astronomia dell'Università and INFN, Sezione di Padova, I-35131 Padova, Italy
[j] Extreme Light Infrastructure – Nuclear Physics, Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), 077125 Bucharest-Măgurele, Romania

ARTICLE INFO

Article history:
Received 18 June 2021
Received in revised form 26 August 2021
Accepted 24 October 2021
Available online 29 October 2021
Editor: B. Blank

ABSTRACT

A sequence of excited states has been established for the first time in the proton-ri
(Z=26, N=22). The technique of mirrored (i.e. analogue) one-nucleon knockout reactio
in which the $T_z = \pm 2$ mirror pair, ^{48}Fe/^{48}Ti were populated via one-neutron/one-proton
the secondary beams ^{49}Fe/^{49}V, respectively. The analogue properties of the reactions we
establish the new level scheme of ^{48}Fe. The inclusive and exclusive cross sections w
for the populated states. Large differences between the cross sections for the two mi
were observed and have been interpreted in terms of different degrees of binding of th
and in the context of the recent observations of suppression of spectroscopic strength
nuclear binding, for knockout reactions on light solid targets. Mirror energy differences (
determined between the analogue $T = 2$ states and compared with the shell model predi
this mirror pair, due to their location in the shell, are especially sensitive to excitations
shell, and present a stringent test of the shell-model prescription.

1. Introduction

The attractive strong nuclear force that acts between protons and neutrons is virtually invariant to the charge of the individual nucleons. This yields one of the fundamental concepts in nuclear physics - the concept of isospin and the resulting influence of isospin symmetry upon nuclear structure [1,2]. Isospin enables us to describe two types of fermion, the proton and ne
different states of the nucleon and, in this formalism
have isospin quantum number $t = \frac{1}{2}$ with different
a proton ($t_z = -\frac{1}{2}$) and for a neutron ($t_z = +\frac{1}{2}$). Mor
cleus has a total isospin projection on the z-axis T_z
isospin of the individual nucleons, denoted by quant
is given by:

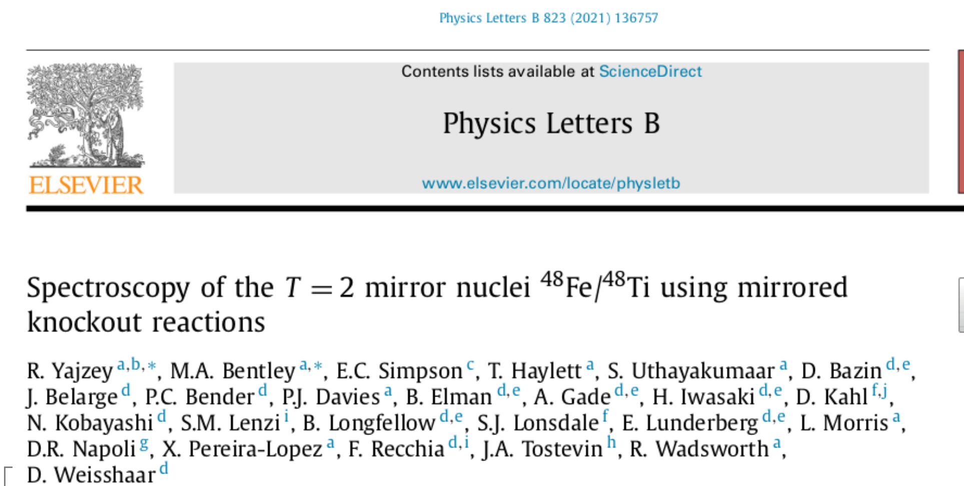
$$T_z = \sum t_z = \frac{N - Z}{2}$$

* Corresponding authors.

Isospin symmetry

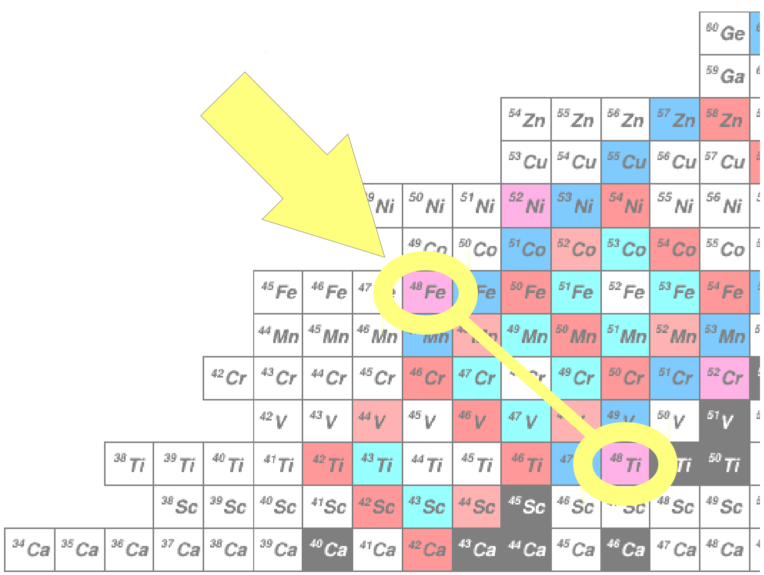
Isospin-symmetry-breaking probes include:

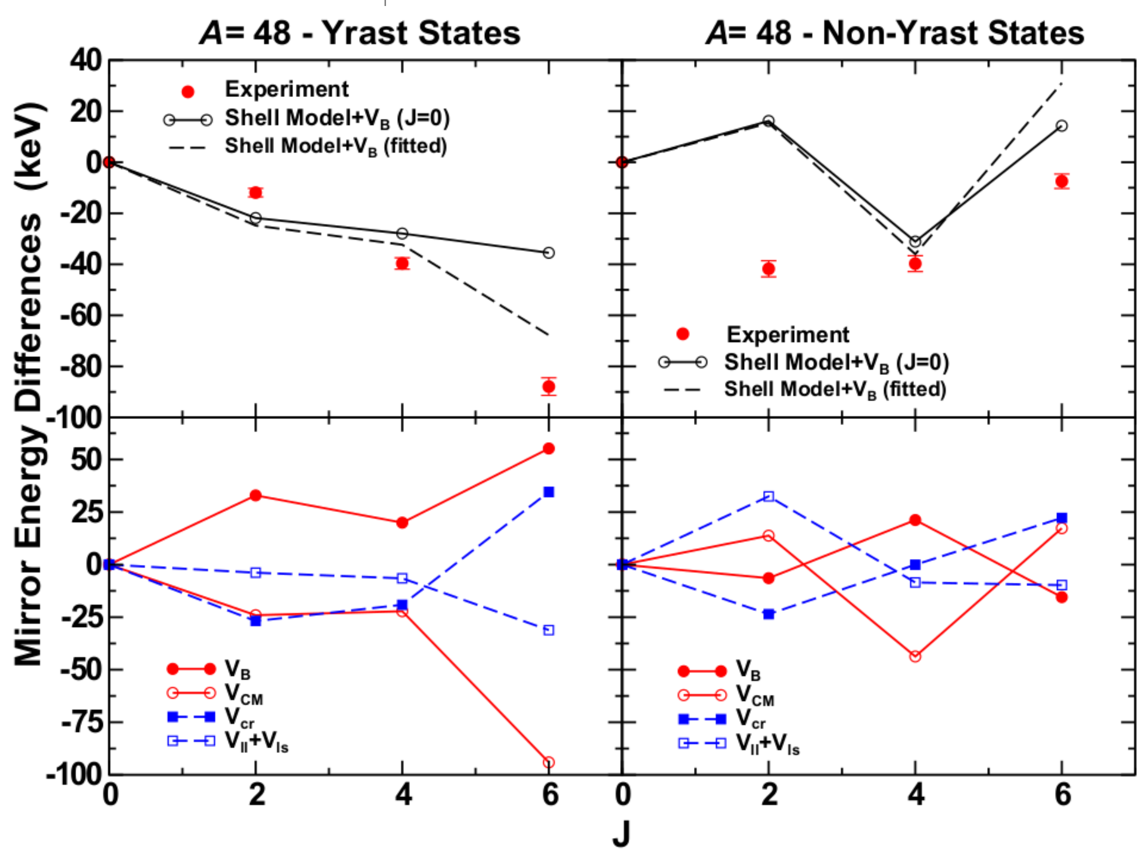
- **Mirror energy differences (MED)**
- **Triplet energy differences (TED)**
- Coulomb energy differences (CED)


Physics Letters B 823 (2021) 136757
Contents lists available at ScienceDirect
Physics Letters B
www.elsevier.com/locate/physletb
ELSEVIER

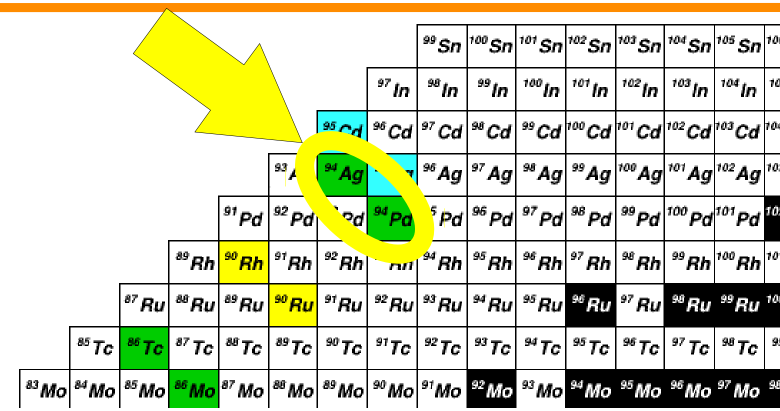
Spectroscopy of the $T = 2$ mirror nuclei ^{48}Fe/^{48}Ti using mirrored knockout reactions

R. Yajzey[a,b,*], M.A. Bentley[a,*], E.C. Simpson[c], T. Haylett[a], S. Uthayakumaar[a], D. Bazin[d,e], J. Belarge[d], P.C. Bender[d], P.J. Davies[a], B. Elman[d,e], A. Gade[d,e], H. Iwasaki[d,e], D. Kahl[f,j], N. Kobayashi[d], S.M. Lenzi[i], B. Longfellow[d,e], S.J. Lonsdale[f], E. Lunderberg[d,e], L. Morris[a], D.R. Napoli[g], X. Pereira-Lopez[a], F. Recchia[d,i], J.A. Tostevin[h], R. Wadsworth[a], D. Weisshaar[d]



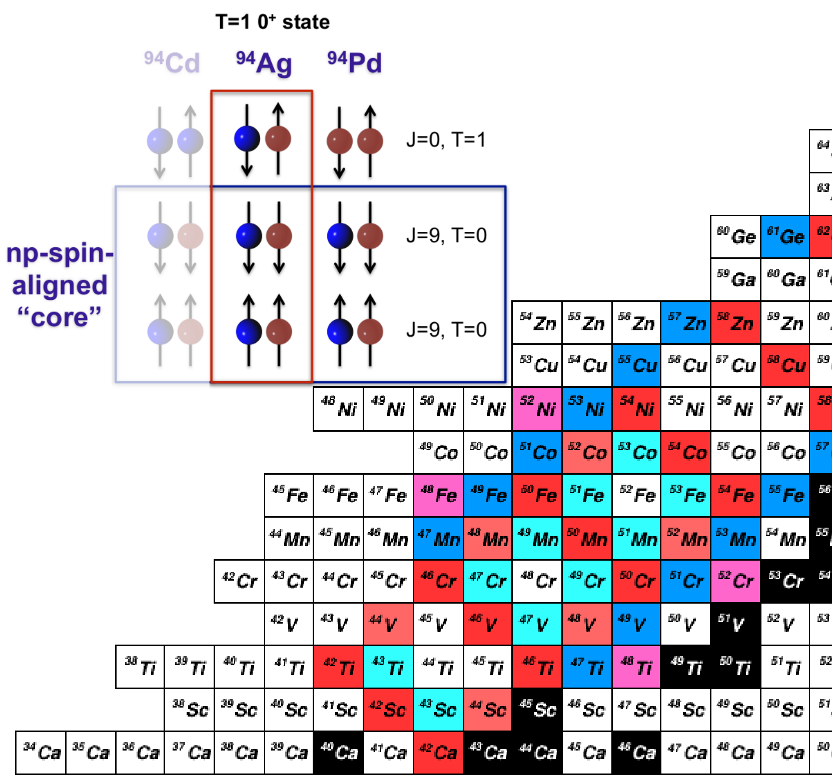


Isospin symmetry



Isospin-symmetry-breaking probes include:

- Mirror energy differences (MED)
- Triplet energy differences (TED)
- Coulomb energy differences (CED)



In-beam γ-ray spectroscopy of ^{94}Ag

X. Pereira-López,[1,2] M.A. Bentley,[1] R. Wadsworth,[1] P. Ruotsalainen,[3] S.M. Lenzi,[4,5] U. Forsberg,[1,6] K. Aurane
A. Blazhev,[7] B. Cederwall,[8] T. Grahn,[3] P. Greenlees,[3] A. Illana,[3] D.G. Jenkins,[1] R. Julin,[3] H. Jutila,[3] S. Juutine
X. Liu,[8] R. Llewelyn,[1] M. Luoma,[3] K. Moschner,[7] C. Müller-Gatermann,[7] B.S. Nara Singh,[9,10] F. Nowacki,[11]
Ojala,[3] J. Pakarinen,[3] P. Papadakis,[12] P. Rahkila,[3] J. Romero,[3,13] M. Sandzelius,[3] J. Sarén,[3] H. Tann,[3,13] S.
Uthayakumaar,[1] J. Uusitalo,[3] J.G. Vega-Romero,[1] J.M. Vilhena,[9] R. Yajzey,[1,14] W. Zhang,[8] and G. Zimba[3]

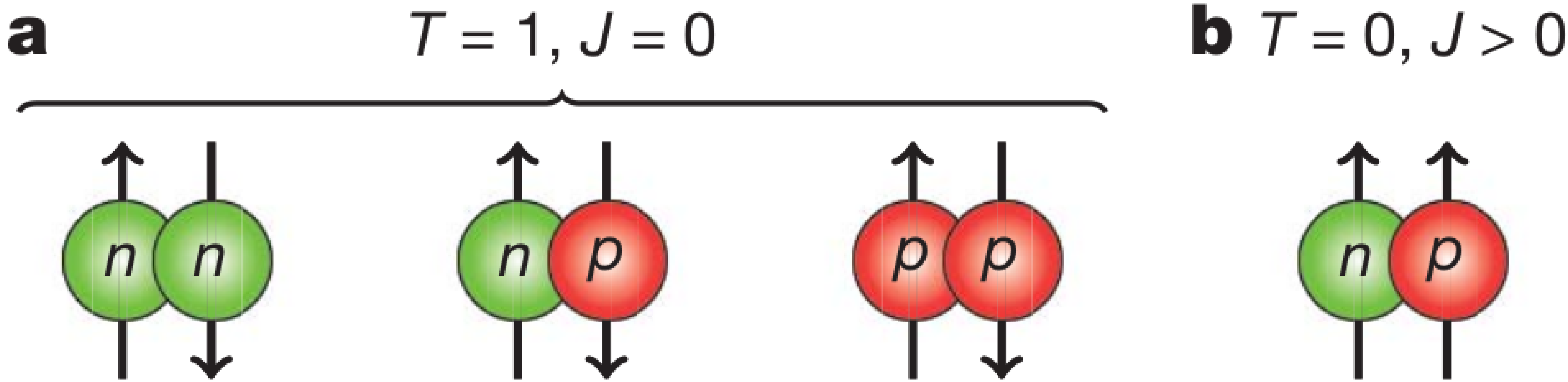
[1]*Department of Physics, University of York, Heslington, York YO10 5DD, United Kingdom*
[2]*Center for Exotic Nuclear Studies, Institute for Basic Science (IBS), Daejeon 34126, Republic of Korea*
[3]*Department of Physics, University of Jyväskylä, P.O. Box 35, FI-40014 Jyväskylä, Finland*
[4]*Dipartimento di Fisica e Astronomia "Galileo Galilei", Università di Padova, I-35131 Padova, Italy*
[5]*INFN, Sezione di Padova, I-35131 Padova, Italy*
[6]*Department of Physics, Lund University, SE-22100 Lund, Sweden*
[7]*Institute of Nuclear Physics, University of Cologne, D-50937 Cologne, Germany*
[8]*Department of Physics, KTH-Royal Institute of Technology, SE-10691 Stockholm, Sweden*
[9]*School of Computing Engineering and Physical Sciences, University of the West of Scotland, Paisley, PA12BE, United Kingdom*
[10]*School of Physics and Astronomy, Schuster Laboratory, Brunswick Street, Manchester M13 9PL, United Kingdom*
[11]*Université de Strasbourg, F-67037 Strasbourg, France*
[12]*STFC Daresbury Laboratory, Daresbury, Warrington, WA4 4AD, United Kingdom*
[13]*Department of Physics, Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 7ZE, United Kingdom*
[14]*Department of Physics, Faculty of Science, Jazan University, Jazan 45142, Saudi Arabia*

(Dated: March 17, 2022)

A recoil-beta-tagging experiment has been performed to study the excited $T = 0$ and $T = 1$ states in odd-odd $N = Z$ ^{94}Ag, using the ^{40}Ca(^{58}Ni,p3n)^{94}Ag reaction. The experiment was conducted using MARA recoil separator and JUROGAM3 array at the Accelerator Laboratory of the University of Jyväskylä. Through correlating fast, high-energy beta decays at the MARA focal plane with prompt γ-rays emitted at the reaction target, a number of transitions between excited states in ^{94}Ag have been identified. The timing characteristics of these transitions confirm that they fall within decay sequences that feed the short-lived $T = 1$ ground state of ^{94}Ag. The transitions are

Nucleon pairing

- Like-nucleon pairing (nn and pp) is the dominant pairing correlation.
- In N~Z systems, np pairings are possible.



- Evidence of spin-aligned T=0 np pairing is elusive.
  - Rotational alignment in ^{88}Ru
  - Yrast sequence in ^{92}Pd

B. Cederwall et al., Nature 461, (2011) 6871.

- Theory studies suggested similar effect in N=Z A>90 ^{94}Ag and ^{96}Cd

G.J.Fu, J.J Shen, Y.M. Zhao and A. Arima, PRC 87 (2013) 044312
Z.X.Xu, C. Qi, J. Blomqvist, R.J. Liotta and R. Wyss, Nucl. Phys. A 877 (2012) 51-58
S. Zerguine and P. Van Isacker, PRC 83 (2011) 064314.

Current knowledge on ^{94}Ag

- Several experimental studies have been focused on ^{94}Ag:

[1] J. Park et al., PRC 99, 034313 (2019).
[2] K. Moschner et al., EPJ web conf. 93, (2015) 01024.
[3] M. La Commara et al., Nucl. Phys. A 708 (2002) 167-180.
[4] I. Mukha et al., PRC 70 (2004) 044311.
[5] I. Mukha et al., PRL 95 (2005) 022501.
[6] K. Schmidt et al., Z. Phys. A 350 (1994) 99-100.
[7] C. Plettner et al., Nucl. Phys. A 733 (2004) 20-36.
[8] E. Roeckl, Int. J. Mod. Phys. E 15, 2 (2006) 368-373.
[9] O.L. Pechenaya et al., PRC 76 (2007) 011304(R).
[10] T. Kessler et al., Nucl. Instrum. Methods PRB 266 (2008) 4420-4424.
[11] A. Kankainen et al., PRL 101 (2008) 142503.
[12] K. Kaneko et al., AIP Conference Proceedings 1090 (2009) 611.
[13] J. Cerny et al., PRL 103 (2009) 152502.
[14] David G. Jenkins, PRC 80 (2009) 054303.
[15] I. Mukha et al., arXiv:1008.5346 [nucl-ex] (2009).
[16] Mamta Aggarwal, PLB 693 (2010) 489-493.

- However, current knowledge is limited to:
  - 0^+ ground state, half life of 27(2) ms [1,2]
  - Two isomeric states:
    - (7^+) [3] half life of 0.50(1) ms [1,4] located at 6.7 MeV [5]. β, β-delayed p and p
    - (21^+) [3] half life of 0.39(4) ms [4]

Experimental setup

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

Experimental setup

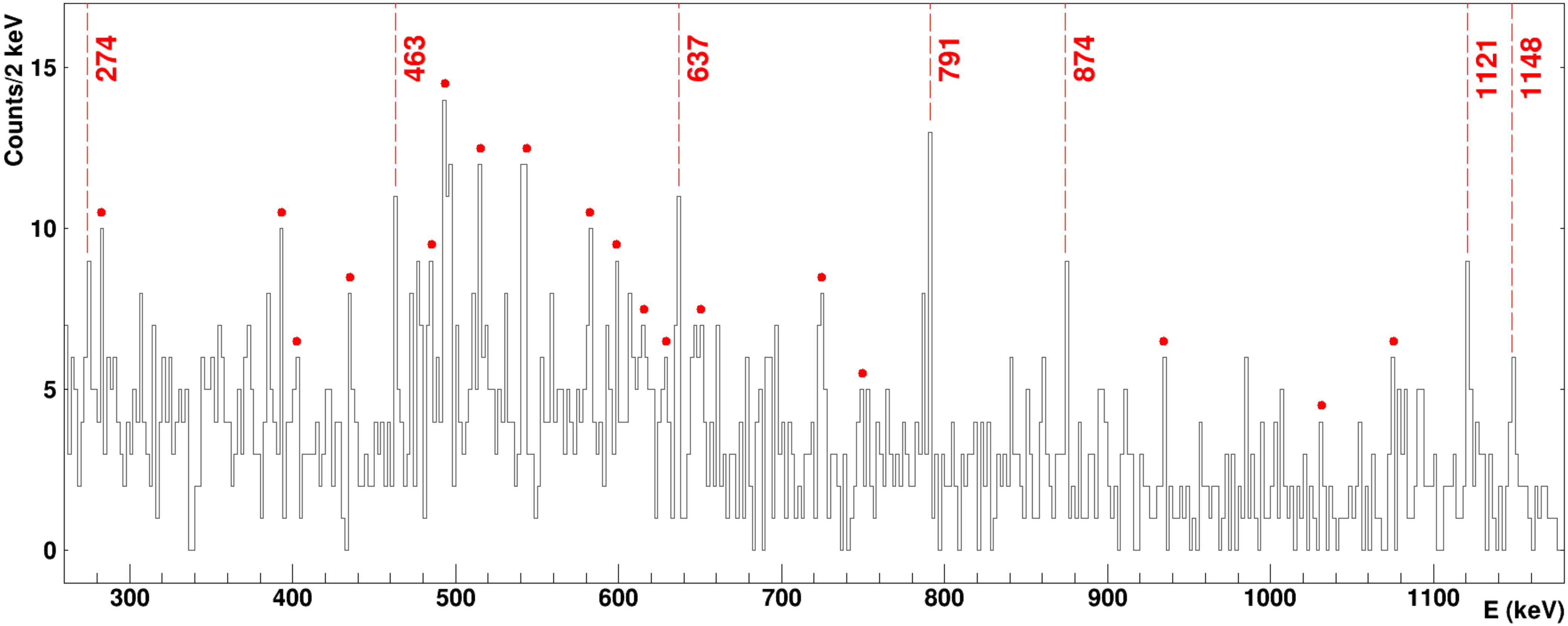
Fusion-evaporation reaction $^{40}Ca(^{58}Ni,p3n)^{94}Ag$

- All detector signals are time stamped to allow temporal correlations.

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

^{94}Ag transitions

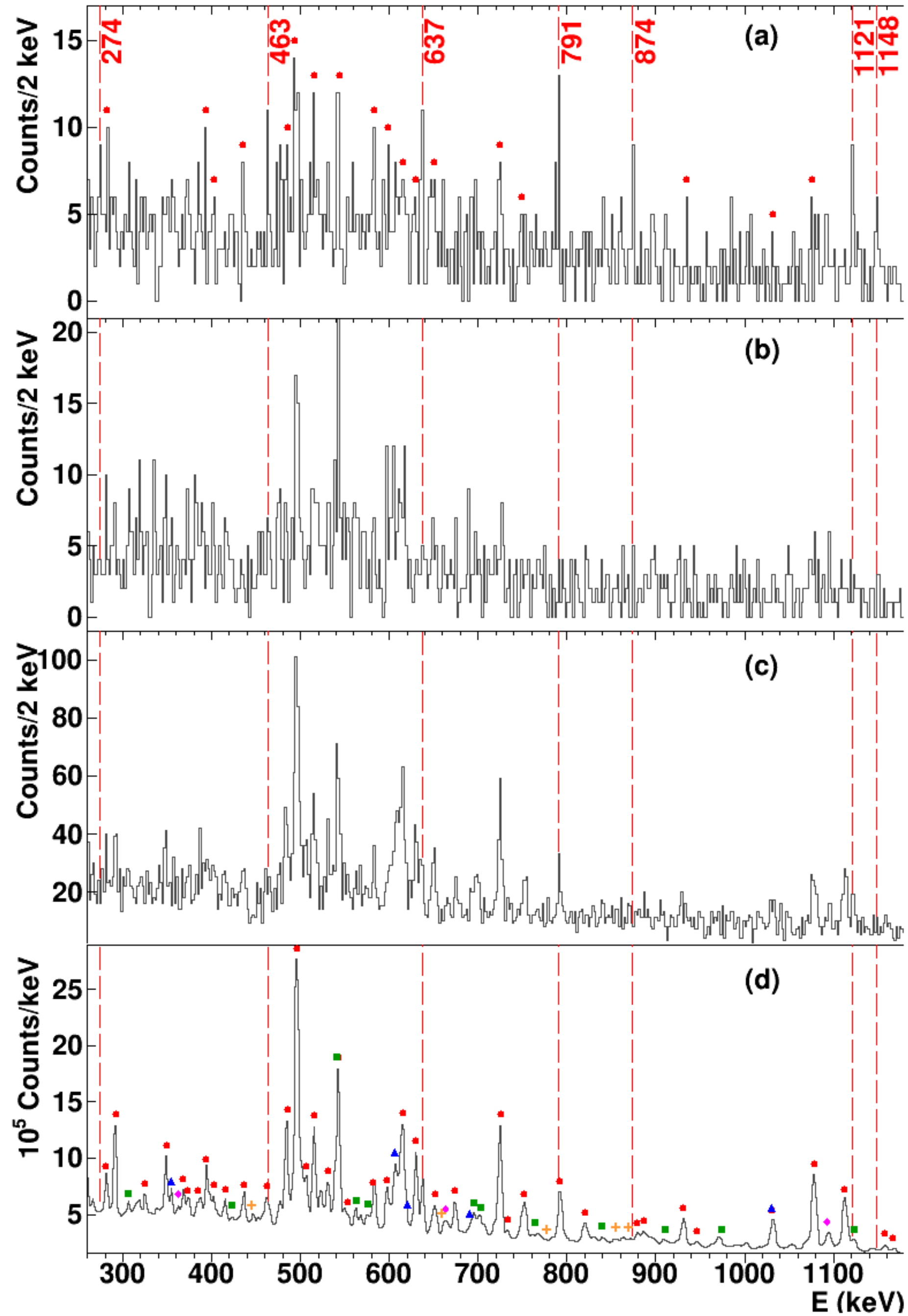
- ^{94}Ag transitions were identified in the Doppler corrected γ-ray spectra for:
  - Prompt emission
  - short-lived A=94 fragments (decay within 60ms)
  - One or less charged particles
  - High energy β (E > 3 MeV)



^{94}Ag transitions

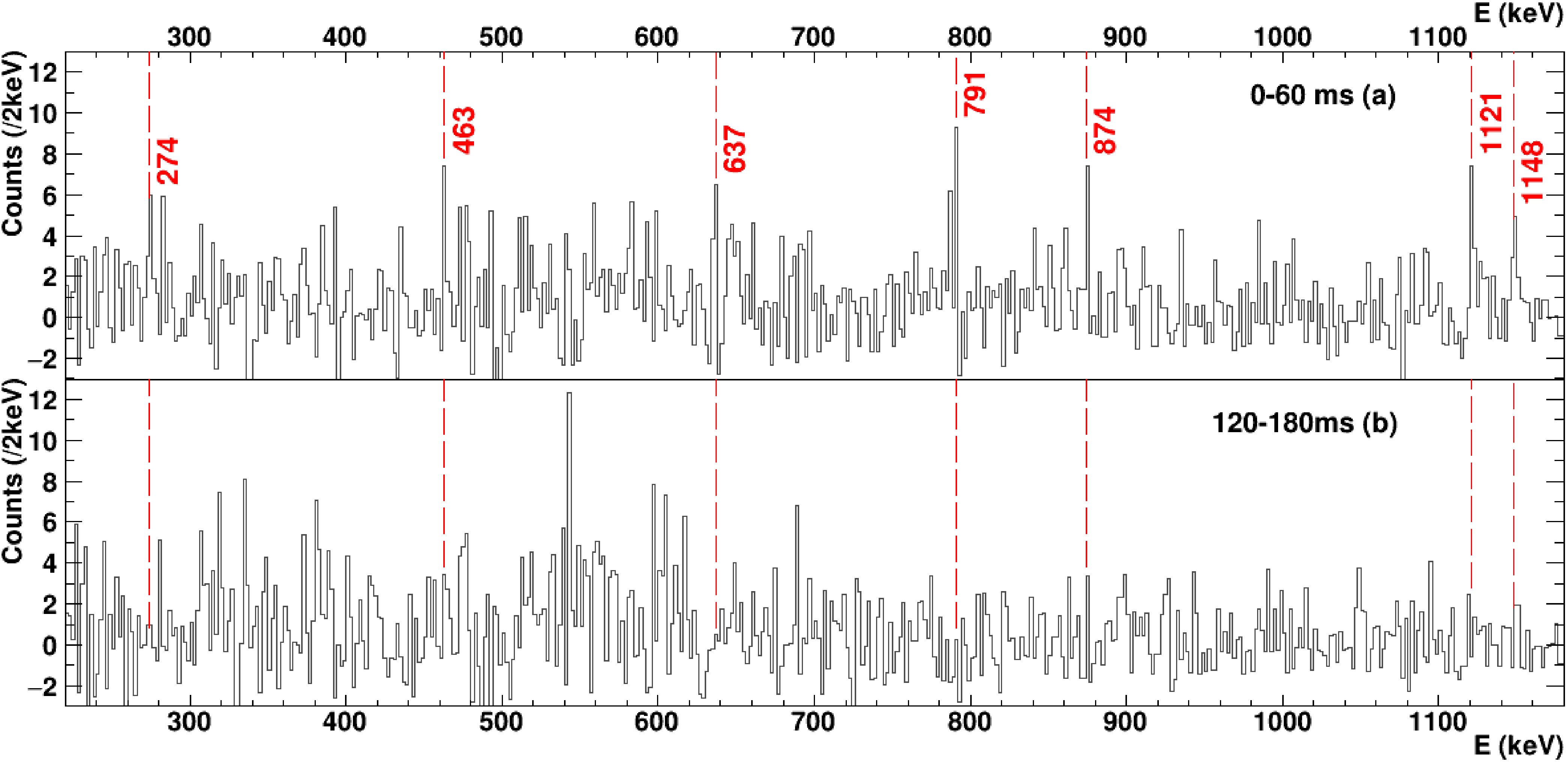
- Comparison with spectra recorded for
    - b) higher charged particle multiplicity
    - c) Longer lived A=94 recoils
        - - decay between 120 and 180 ms
    - d) A=94 recoil

- γ-rays at 273, 463, 637, 791, 874, 1121 and 1148 keV seem to grow respect to other A=94 contaminants when gating on the reaction channel leading to ^{94}Ag.
    - Most contaminants are ^{94}**Ru** transitions.
        - - evidence of ^{94}**Rh**, ^{94}**Tc** and ^{90}**Mo**
    - They come from either:
        - - false correlations
        - - misidentified p3n events



^{94}Ag transitions

Background substracted Doppler corrected spectra for prompt γ-rays for A=94 recoils decaying withing 60ms (a) or 120-180ms (b), in coincidence with a high energy β and rejecting events with 2 or more charged particles in JYtube.

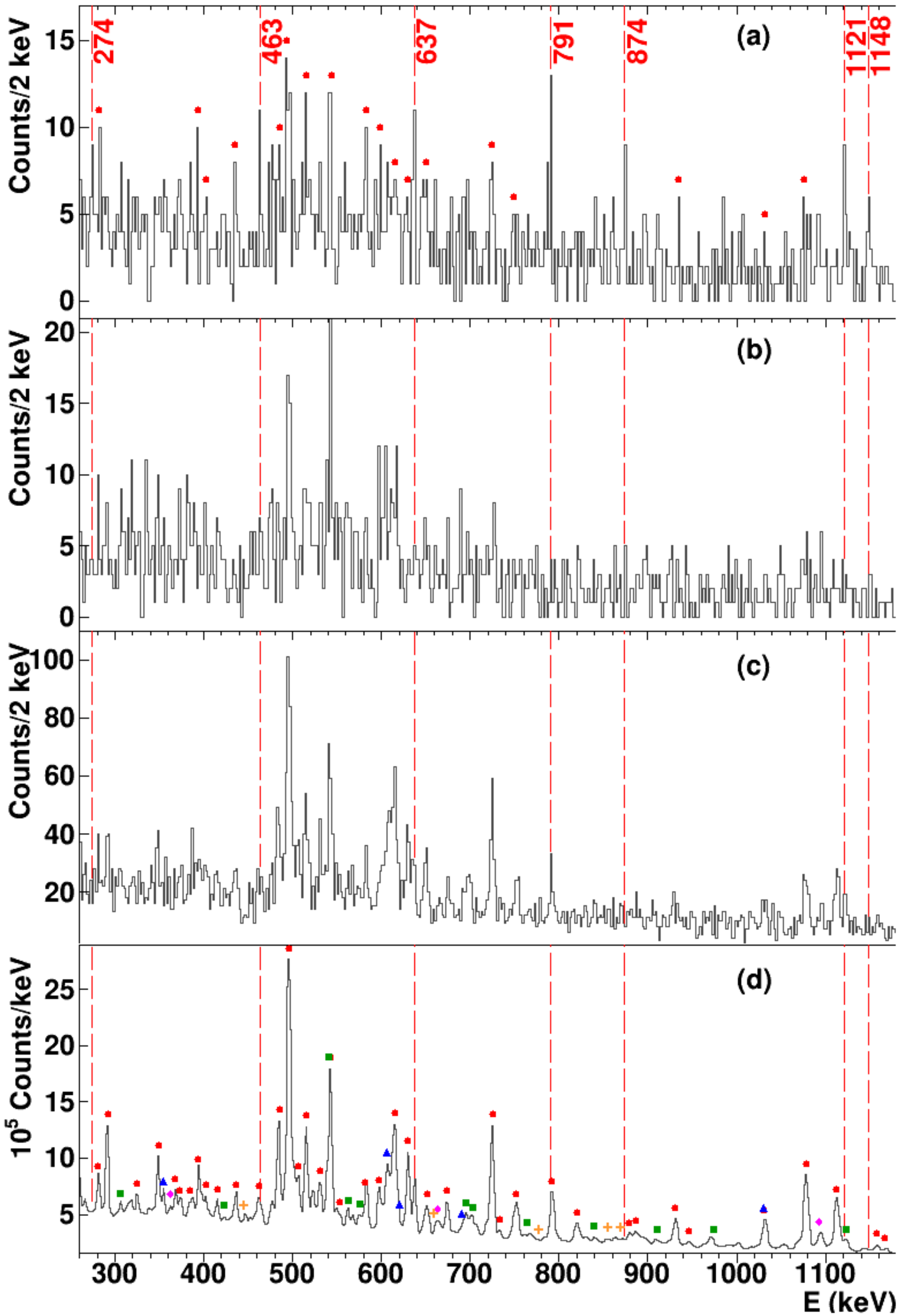


^{94}Ag transitions

- Comparison with spectra recorded for
  - b) higher charged particle multiplicity
  - c) Longer lived A=94 recoils
    - - decay between 120 and 180 ms
  - d) A=94 recoil

γ-rays observed in this work are associated with a short lived A=94 nucleus, produced via one charged particle evaporation channel and whose half-life is consistent with currently accepted value for ^{94}Ag ground state β-decay.

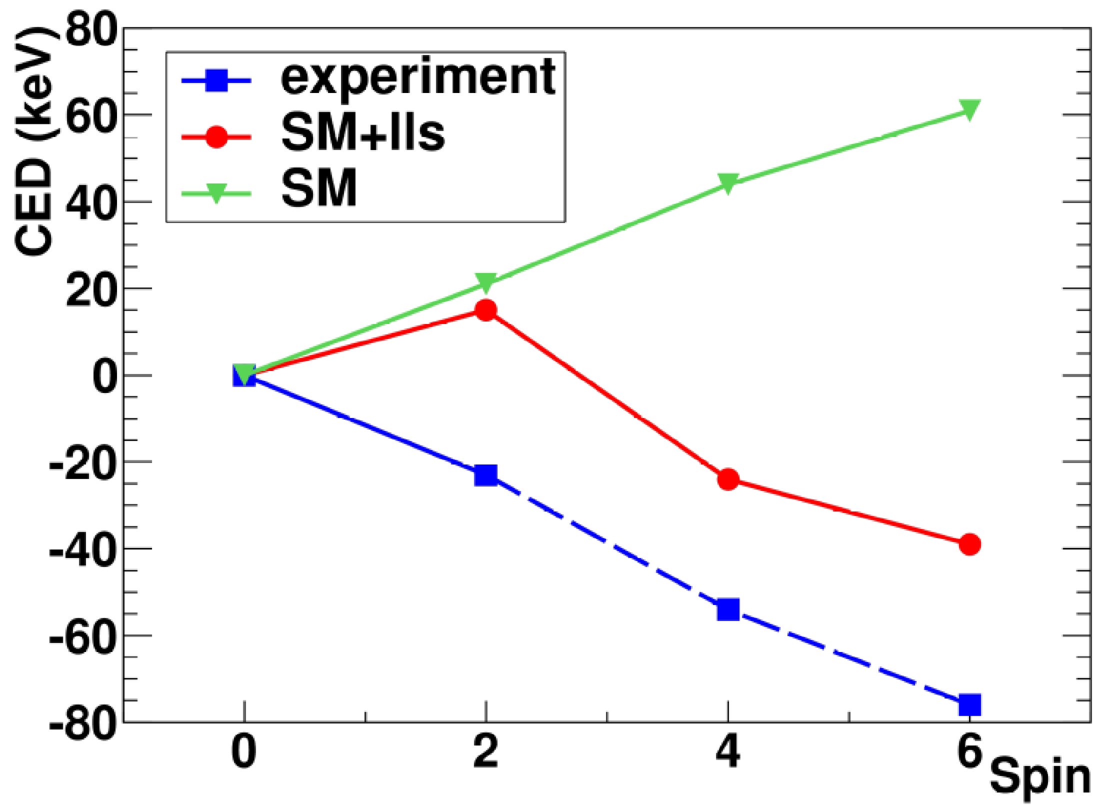
- Not enough statistics for γ-γ analysis.



CEDs

- Based on comparison with ^{94}Pd
  - 791, 874 and 637 keV in ^{94}Ag

    analog states of
  - 814, 905 and 659 keV in ^{94}Pd
- Negative CEDs
  - Observed only for ^{70}Br-^{70}Se
- Compared to SM calculations
  - JUN45, fpg model space
  - decresing trend
  - ~35 keV shift



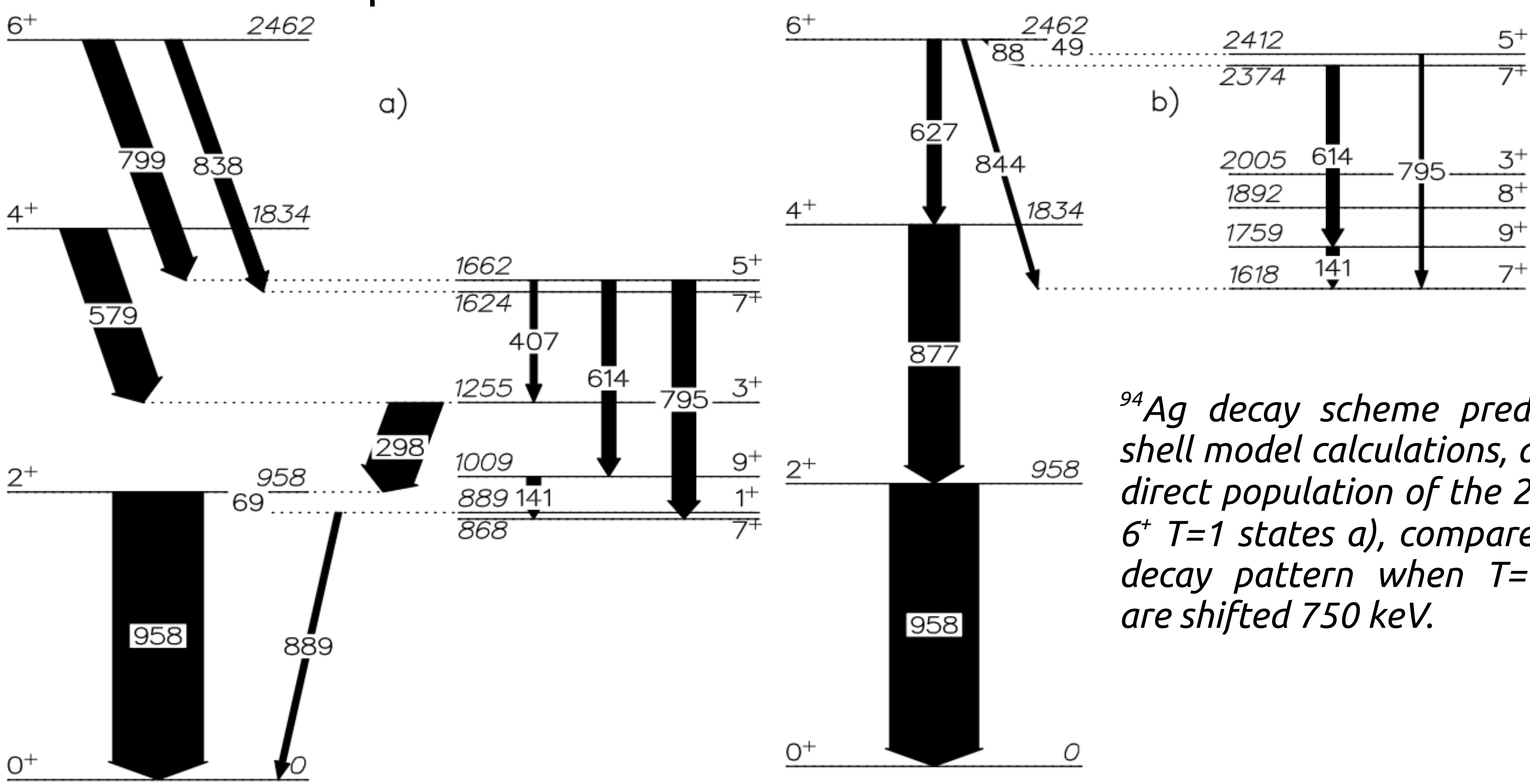
CEDs as function of J between tentatively assigned T=1 levels in ^{94}Ag and analog states in ^{94}Pd. ***Experimental values*** *in blue squares,* ***SM model prediction*** *in red circles.*

Shell model predictions

- SM suggest that we should only see $2^+ \rightarrow 0^+$ T=1 decay.
- However, if T=0 lie 750 keV higher, E2 sequence from 6^+ becomes dominant.
- Location of T=0 strongly influenced by np aligned $g_{9/2}$ matrix element.

Z.X.Xu, C. Qi, J. Blomqvist, R.J. Liotta and R. Wyss, Nucl. Phys. A 877 (2012) 51-58

- Further work is required



^{94}Ag decay scheme predicted by shell model calculations, assuming direct population of the 2^+, 4^+ and 6^+ T=1 states a), compared to the decay pattern when T=0 states are shifted 750 keV.

Conclusions

- Seven γ-ray transitions observed in this work are associated with a short lived A=94 nucleus, produced via one charged particle evaporation channel and whose half-life is consistent with currently accepted value for ^{94}Ag ground state β-decay.
    - They represent the first observation of γ-ray transitions from ^{94}Ag excited states.
- Results compared with neighbouring T=1 isobar nucleus ^{94}Pd.
- CEDs are extracted and discussed with shell model calculations.
    - Level scheme remains unclear.
- Future experiments to locate the 7^+ T=0 isomer may provide important information regarding the influence of the spin-aligned np pairing scheme in ^{94}Ag.

Collaborators

In-beam γ-ray spectroscopy of ^{94}Ag

X. Pereira-López,[1,2] M.A. Bentley,[1] R. Wadsworth,[1] P. Ruotsalainen,[3] S.M. Lenzi,[4,5] U. Forsberg,[1,6] K. Auranen,[3] A. Blazhev,[7] B. Cederwall,[8] T. Grahn,[3] P. Greenlees,[3] A. Illana,[3] D.G. Jenkins,[1] R. Julin,[3] H. Jutila,[3] S. Juutinen,[3] X. Liu,[8] R. Llewelyn,[1] M. Luoma,[3] K. Moschner,[7] C. Müller-Gatermann,[7] B.S. Nara Singh,[9,10] F. Nowacki,[11] J. Ojala,[3] J. Pakarinen,[3] P. Papadakis,[12] P. Rahkila,[3] J. Romero,[3,13] M. Sandzelius,[3] J. Sarén,[3] H. Tann,[3,13] S. Uthayakumaar,[1] J. Uusitalo,[3] J.G. Vega-Romero,[1] J.M. Vilhena,[9] R. Yajzey,[1,14] W. Zhang,[8] and G. Zimba[3]

[1] *Department of Physics, University of York, Heslington, York YO10 5DD, United Kingdom*
[2] *Center for Exotic Nuclear Studies, Institute for Basic Science (IBS), Daejeon 34126, Republic of Korea*
[3] *Department of Physics, University of Jyväskylä, P.O. Box 35, FI-40014 Jyväskylä, Finland*
[4] *Dipartimento di Fisica e Astronomia "Galileo Galilei", Università di Padova, I-35131 Padova, Italy*
[5] *INFN, Sezione di Padova, I-35131 Padova, Italy*
[6] *Department of Physics, Lund University, SE-22100 Lund, Sweden*
[7] *University of Köln, Department of Physics, Zülpicher Str.77, 50937 Köln, Germany*
[8] *Department of Physics, KTH-Royal Institute of Technology, SE-10691 Stockholm, Sweden*
[9] *School of Computing Engineering and Physical Sciences, University of the West of Scotland, Paisley, PA12BE, United Kingdom*
[10] *School of Physics and Astronomy, Schuster Laboratory, Brunswick Street, Manchester M13 9PL, United Kingdom*
[11] *Université de Strasbourg, F-67037 Strasbourg, France*
[12] *STFC Daresbury Laboratory, Daresbury, Warrington, WA4 4AD, United Kingdom*
[13] *Department of Physics, Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 7ZE, United Kingdom*
[14] *Department of Physics, Faculty of Science, Jazan University, Jazan 45142, Saudi Arabia*

CENS CENTER FOR EXOTIC NUCLEAR STUDIES

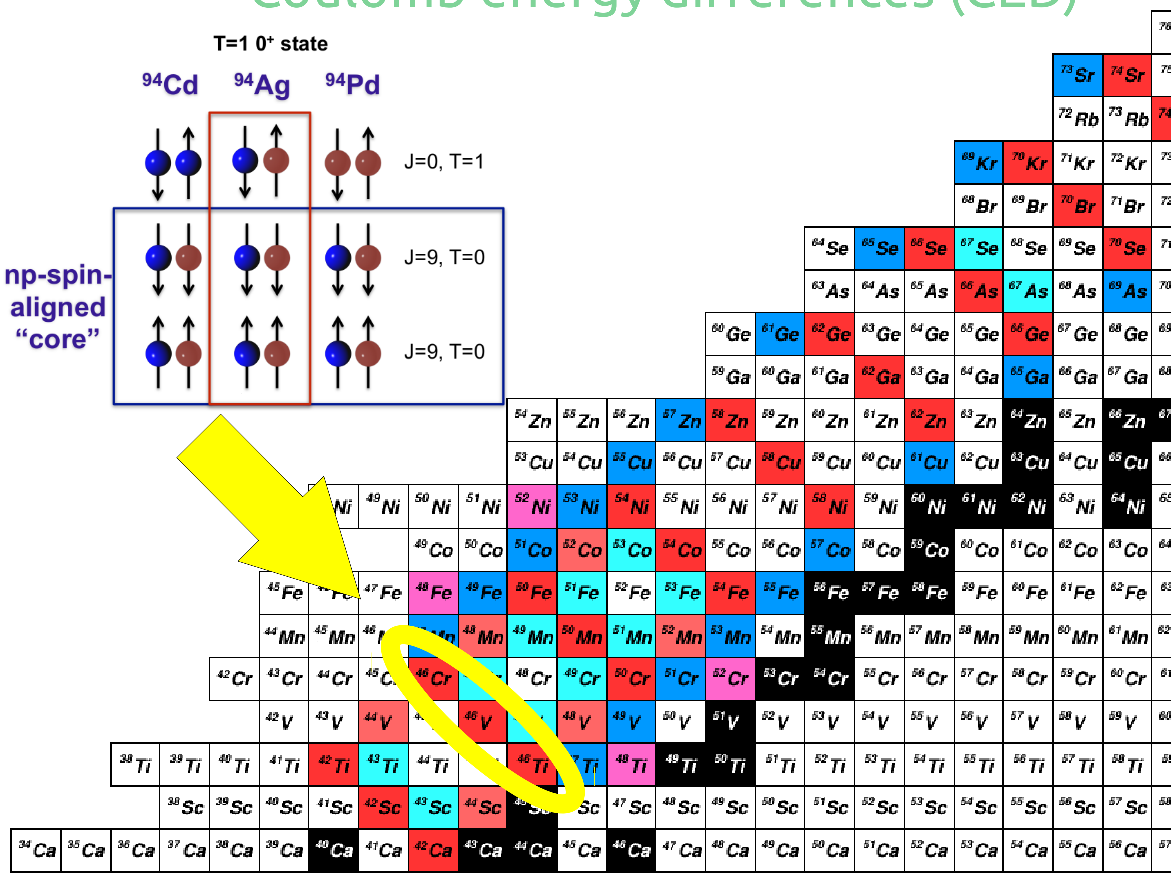
UNIVERSITY of York

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

Isospin symmetry

Isospin-symmetry-breaking probes include:

- Mirror energy differences (MED)
- **Triplet energy differences (TED)**
- Coulomb energy differences (CED)



Physics Letters B 797 (2019) 134835
Contents lists available at ScienceDirect
Physics Letters B
www.elsevier.com/locate/physletb
ELSEVIER

Isospin dependence of electromagnetic transition strengths among a isobaric triplet

A. Boso[a,c], S.A. Milne[b], M.A. Bentley[b,*], F. Recchia[a], S.M. Lenzi[a], D. Rudolph[d], M. Labiche[e], X. Pereira-Lopez[b], S. Afara[f], F. Ameil[g], T. Arici[g,h], S. Aydin[i], M. Axiotis[j], D. Barrientos[k], G. Benzoni[l], B. Birkenbach[m], A.J. Boston[o], H.C. Boston[o], P. Boutachkov A. Bracco[l,p], A.M. Bruce[q], B. Bruyneel[r], B. Cederwall[s], E. Clement[t], M.L. Cortes[g,n], D.M. Cullen[u], P. Désesquelles[v], Zs. Dombràdi[w], C. Domingo-Pardo[x], J. Eberth[m], C. Fahlander[d], M. Gelain[j], V. González[y], P.R. John[a], J. Gerl[g], P. Golubev[d], M. Górska[g], A. Gottardo[z], T. Grahn[aa], L. Grassi[a], T. Habermann[g], L.J. Harkness-Brennan[o], T.W. Hen H. Hess[m], I. Kojouharov[g], W. Korten[r], N. Lalović[d], M. Lettmann[n], C. Lizarazo[g], C. Louchart-Henning[g,n], R. Menegazzo[ab], D. Mengoni[a], E. Merchan[g], C. Michelagnoli[t], B. Million[l], V. Modamio[j], T. Moeller[n], D.R. Napoli[j], J. Nyberg[ac], B.S. Nara Singh[b,u], H. Pai[n], N. Pietralla[n], S. Pietri[g], Zs. Podolyak[ad], R.M. Perez Vidal[x], A. Pullia[p,l], D. Ralet[g,n,t], G. Rainovski[ae], M. Reese[g,n], P. Reiter[m], M.D. Salsac[r], E. Sanchis[y], L.G. Sarmiento[d], H. Schaffner[g], L.M. Scruton[b], P.P. Singh[g,af], C. Stahl[g,n], S. Uthayakumaar[b], J.J. Valiente-Dobón[j], O. Wieland[l]

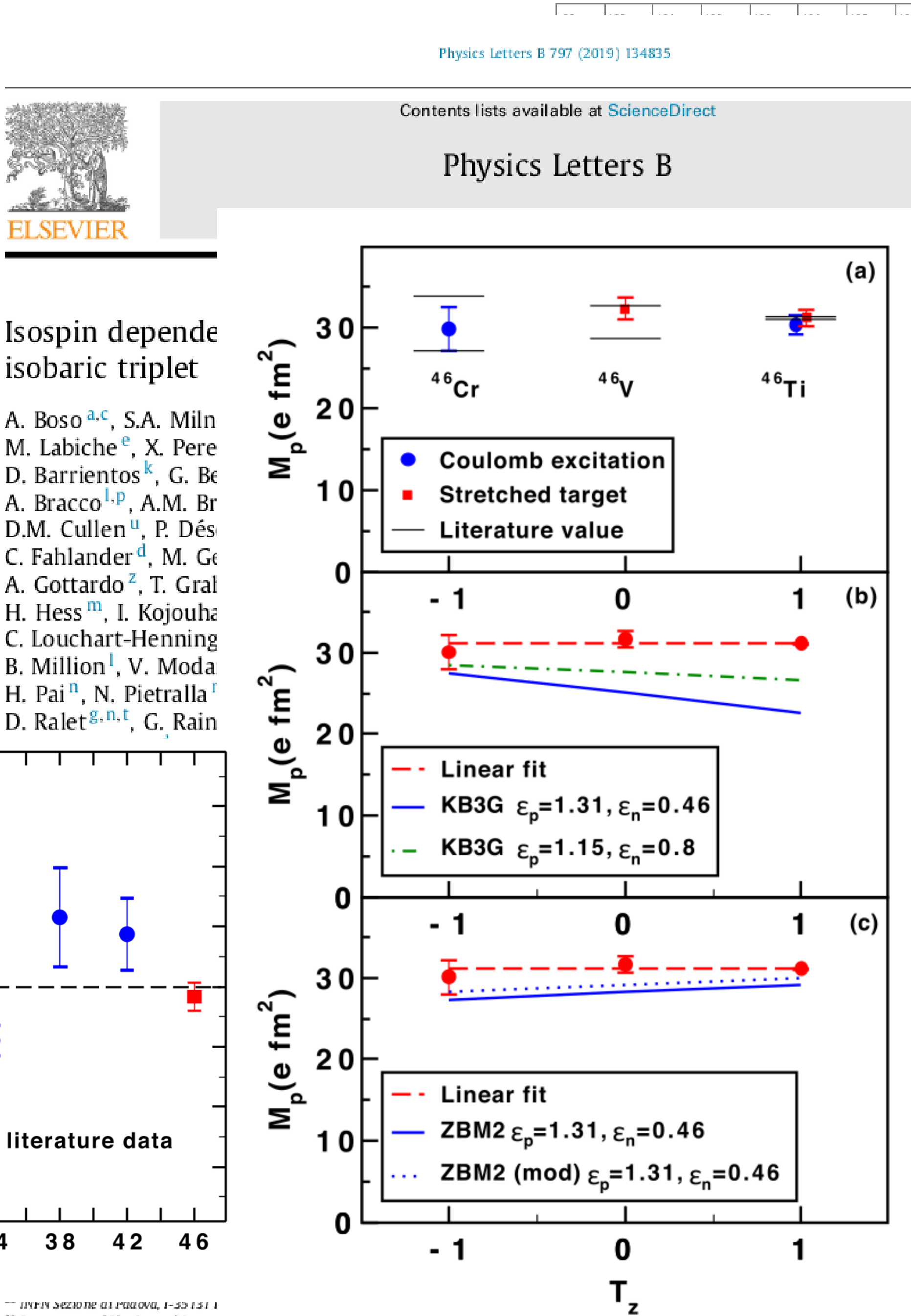
[a] Dipartimento di Fisica e Astronomia "Galileo Galilei", Università di Padova and INFN, Sezione di Padova, I-35131 Padova, Italy
[b] Department of Physics, University of York, Heslington, York, YO10 5DD, United Kingdom
[c] National Physical Laboratory, Hampton Road, Teddington, Middlesex TW11 0LW, United Kingdom
[d] Department of Physics, Lund University, S-22100 Lund, Sweden
[e] UKRI-STFC Daresbury Laboratory, Sci-Tech Daresbury, Daresbury, WA4 4AD, United Kingdom
[f] King Saud University, P. O. BOX 2454, Riyadh 11451, Saudi Arabia
[g] GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt, Germany
[h] Justus-Liebig-Universität Giessen, D-35392 Giessen, Germany
[i] Aksaray University, Bahçe Saray Mahallesi, Aksaray-Adana Yolu, 68100 Sağlık/Aksaray Merkez/Aksaray, Turkey
[j] INFN, Laboratori Nazionali di Legnaro, I-35020 Legnaro, Italy
[k] CERN, CH-1211 Geneva 23, Switzerland
[l] INFN Sezione di Milano, I-20133 Milano, Italy
[m] Institut für Kernphysik, Universität zu Köln, Zülpicher Str. 77, D-50937 Köln, Germany
[n] Institut für Kernphysik, Technische Universität Darmstadt, D-64289 Darmstadt, Germany
[o] Oliver Lodge Laboratory, The University of Liverpool, Liverpool, L69 7ZE, United Kingdom
[p] University of Milano, Dept. of Physics, I-20133 Milano, Italy
[q] School of Computing, Engineering and Mathematics, University of Brighton, Brighton BN2 4GJ, United Kingdom
[r] Irfu, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France
[s] Department of Physics, Royal Institute of Technology, SE-10691 Stockholm, Sweden
[t] GANIL, Bd Henri Becquerel, BP 55027-14076 CAEN Cedex 05 France
[u] School of Physics and Astronomy, The University of Manchester, Oxford Rd, Manchester, M13 9PL, United Kingdom
[v] CSNSM, Université Paris-Sud and CNRS-IN2P3, Universié Paris-Saclay, Bat 104, F-91405 Orsay Campus, France
[w] Institute for Nuclear Research, Hungarian Academy of Sciences, ATOMKI, P.O.Box 51, H-4001 Debrecen, Hungary
[x] IFIC, CSIC-Universitat de Valencia, E-46980 Valencia, Spain
[y] Departamento de Ingeniería Electrónica, Universitat de Valencia, Burjassot, Valencia, Spain
[z] Institut de Physique Nucléaire, IN2P3-CNRS, Université Paris-Sud, Université Paris-Saclay, F-91405 Orsay, France
[aa] Department of Physics, University of Jyväskylä, FIN-40014, Finland
[ab] INFN Sezione di Padova, I-35131 Padova, Italy

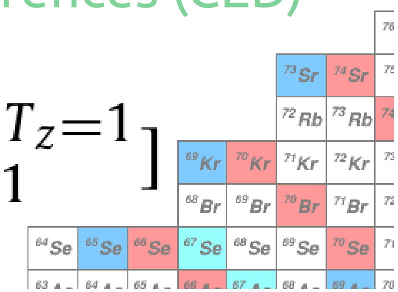
Isospin symmetry

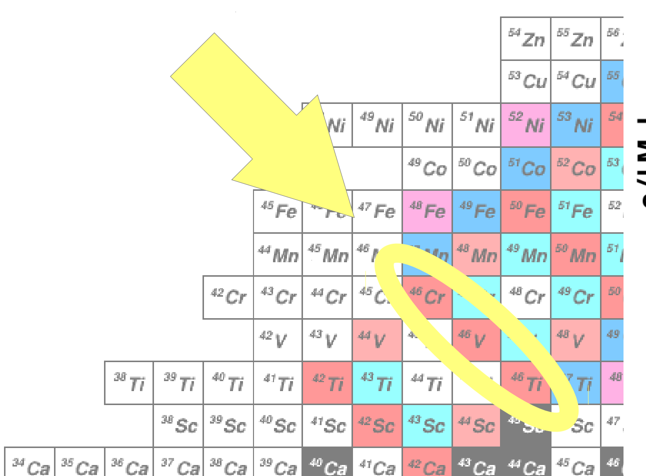
Isospin-symmetry-breaking probes include:

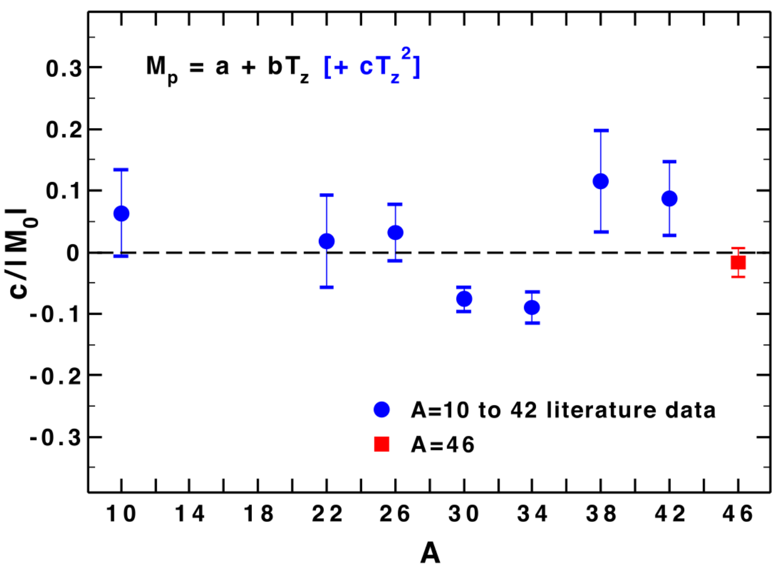
- Mirror energy differences (MED)
- **Triplet energy differences (TED)**
- Coulomb energy differences (CED)

$$M_p(T_z) = \frac{1}{2}[M_0 - T_z M_1^{T_z=1}]$$





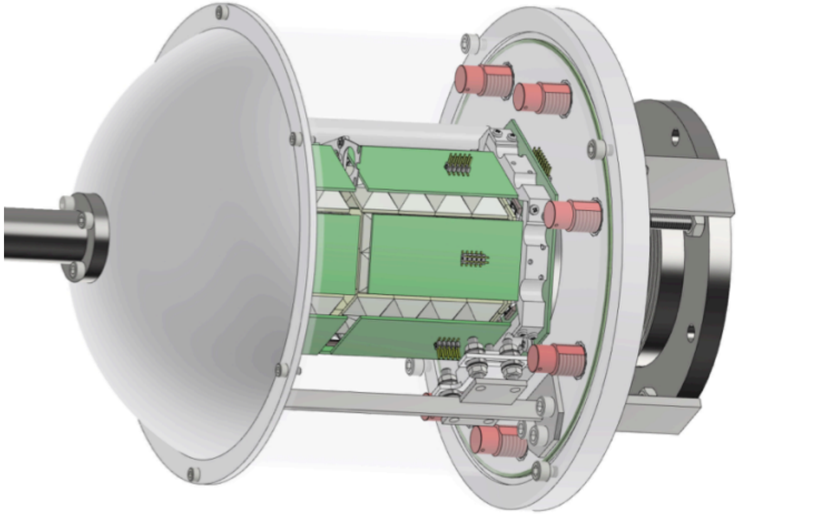


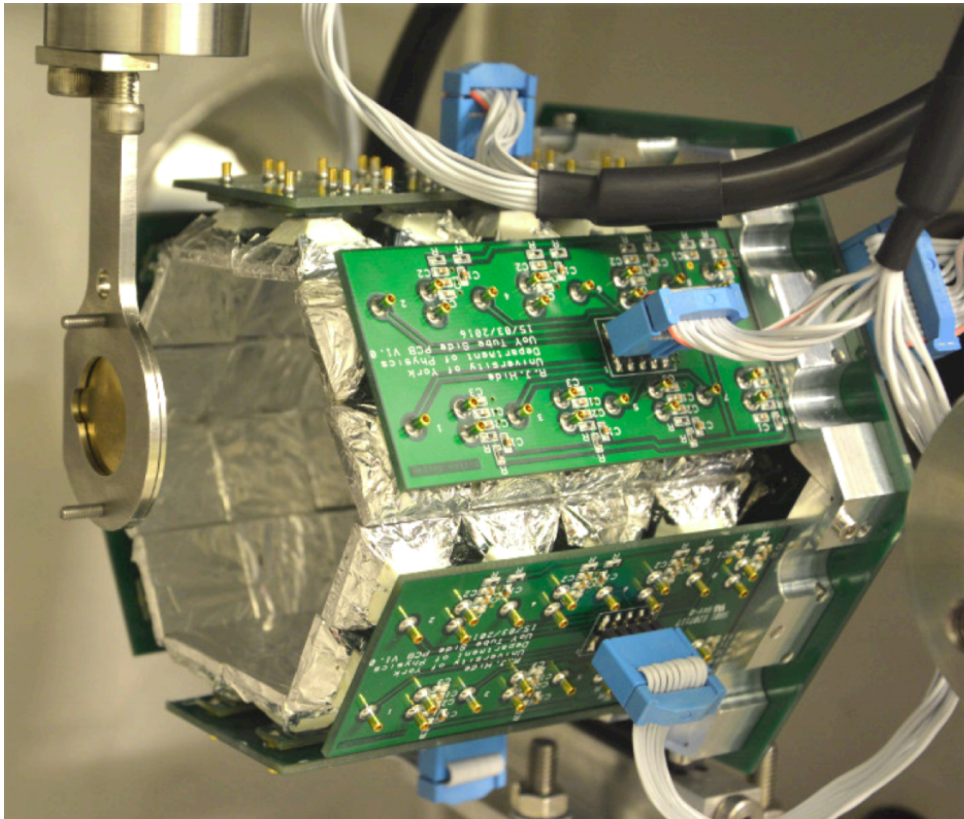


Experimental setup

JYtube

- 96 plastic scintillator crystals.
- Hexagonal shape
- Placed around the target
- Detect evaporated charged particles
    - 65 % efficiency
- Used as a veto detector

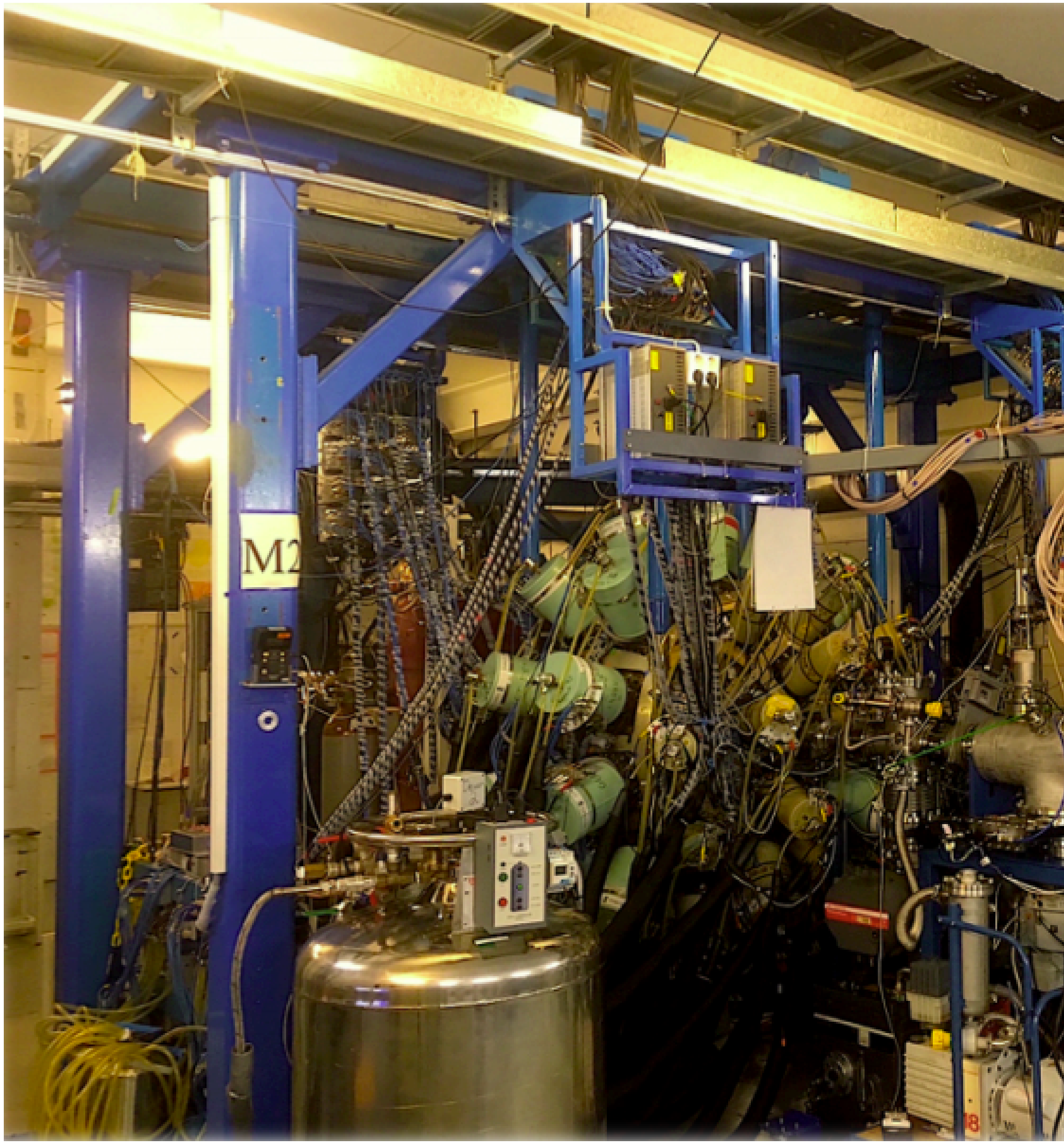




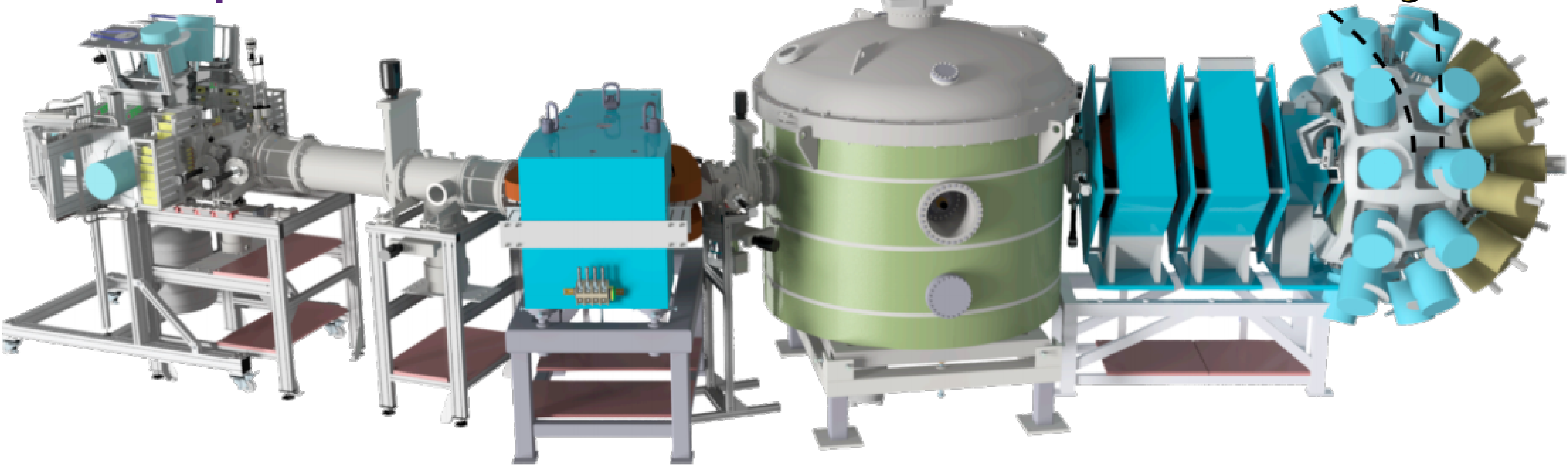
Experimental setup

Jurogam3

- HP Ge detector array
  - 15 single-crystals
  - 24 clover detectors
- BGO Compton suppresion shields
- Placed around the target
  - compact configuration
  - 6% efficiency @ 1.3 MeV
- Prompt γ-rays



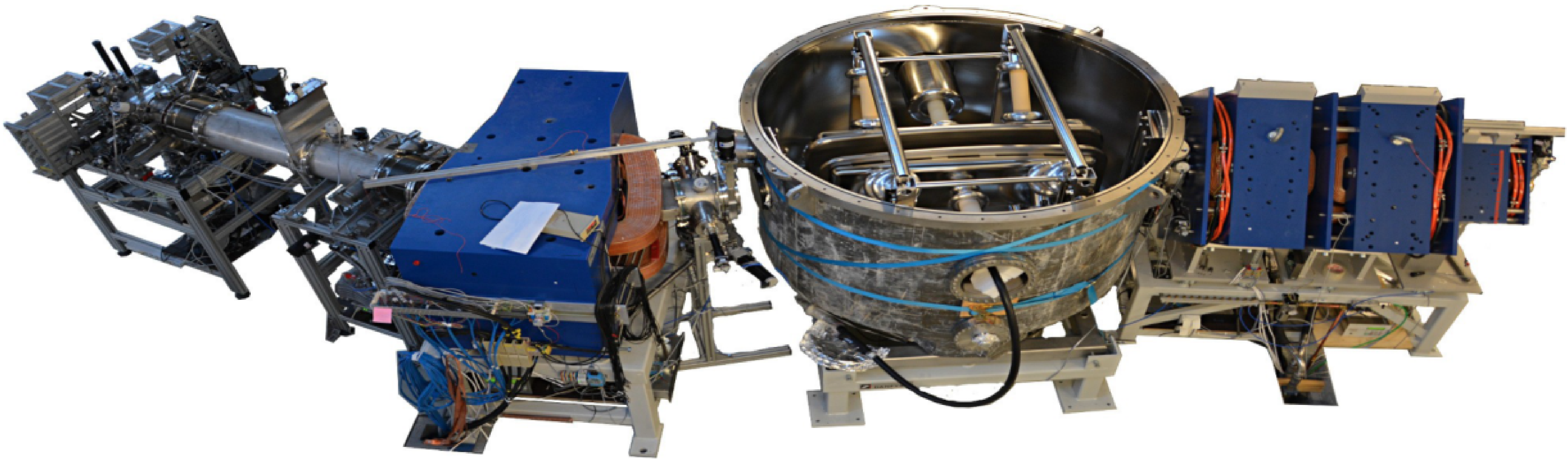
Experimental setup



Experimental setup

MARA

- Perform A/q identification
- Maximise transmission of A=94 fragments to the focal plane detection system.
    - Electric & magnetic field settings
    - Mass slits



Quadrupole triplet, electrostatic deflector and magnetic dipole (from right to left)

Experimental setup

Protons
JYtube

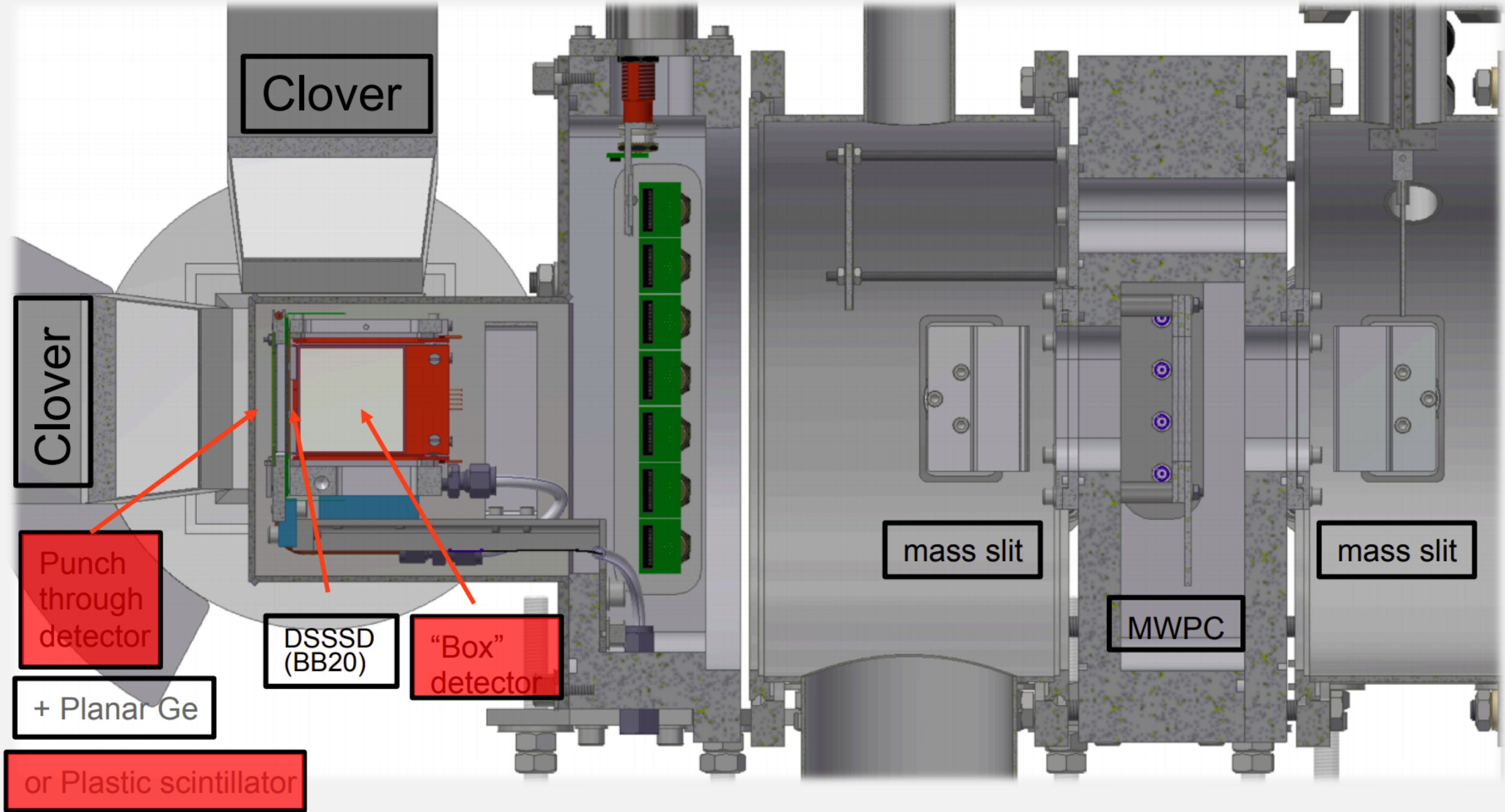
Mass spectrometer
MARA

Fragments & decays
focal plane

prompt γ-rays
Jurogam3

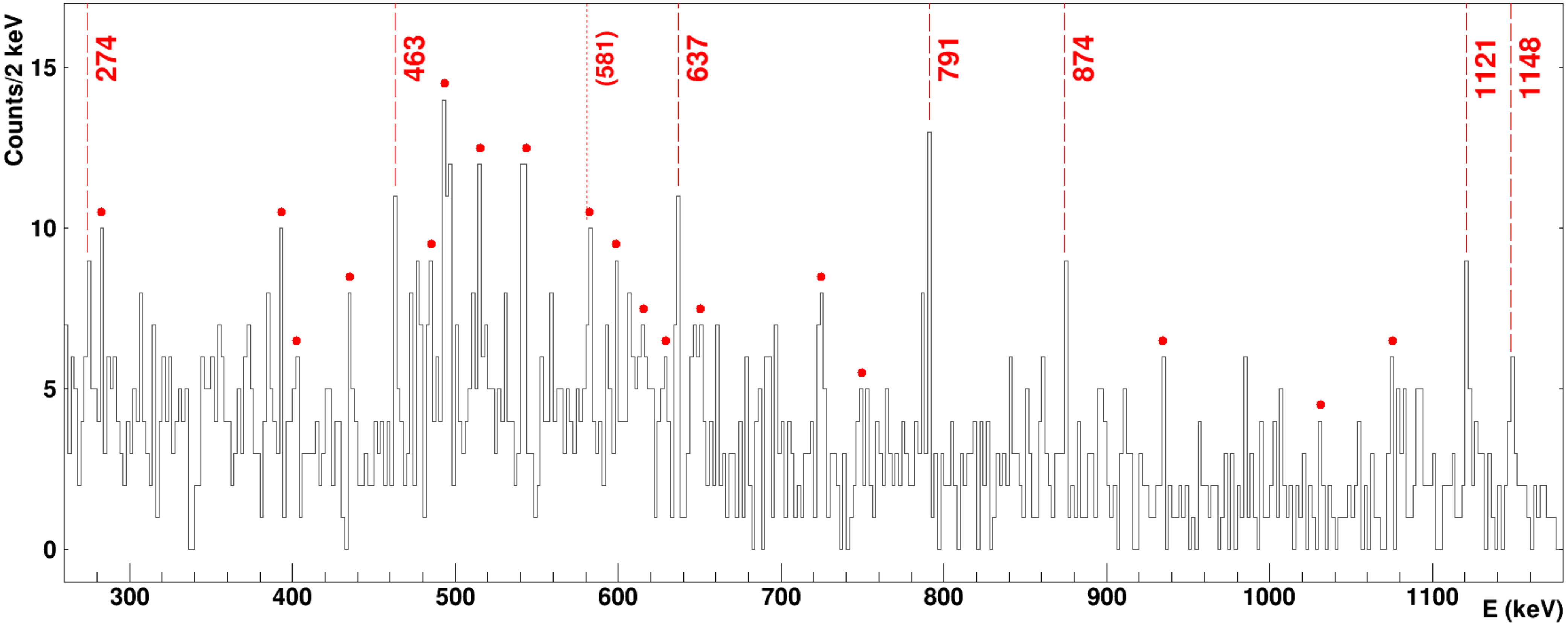
Experimental setup

focal plane



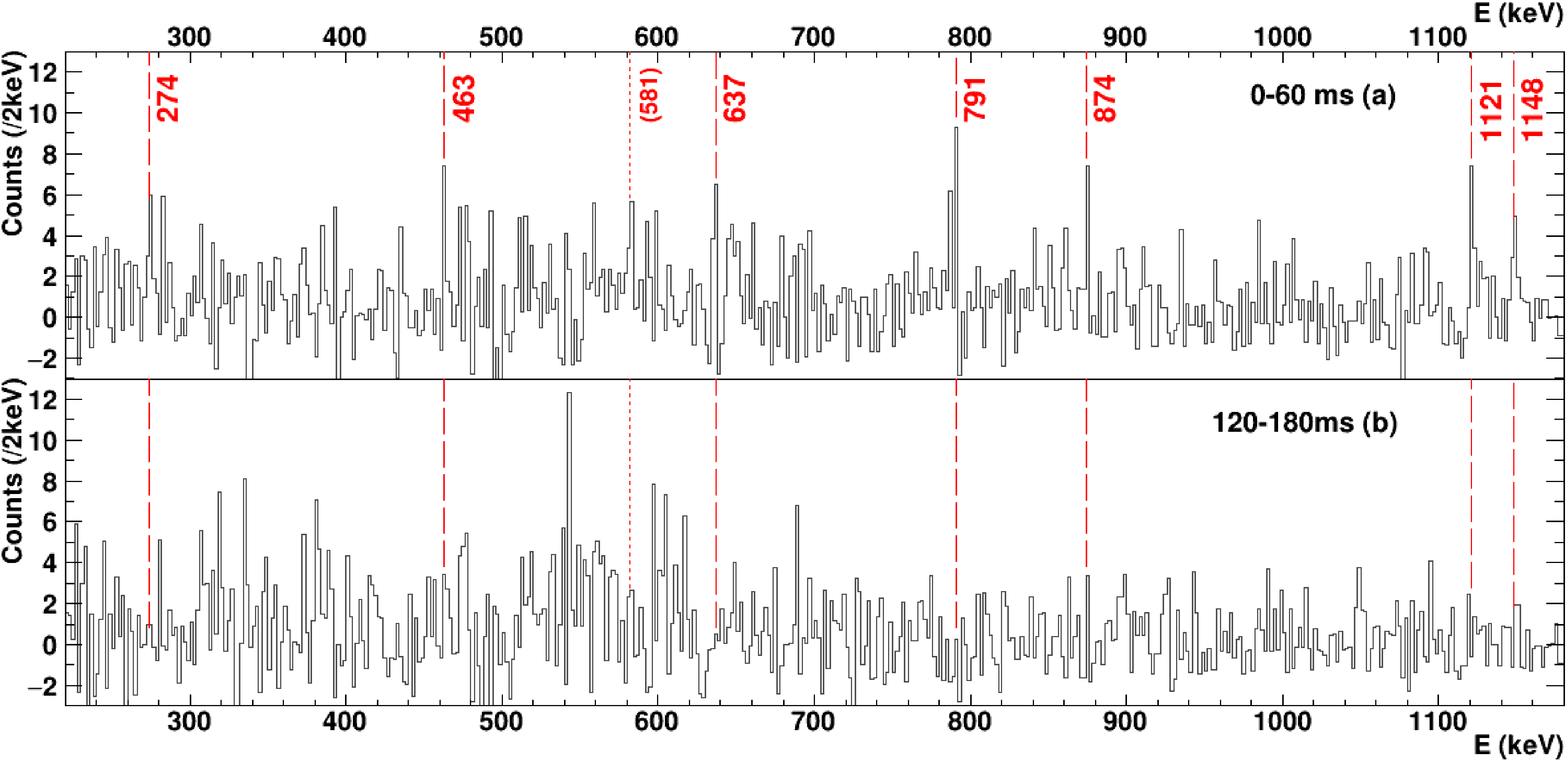
^{94}Ag transitions

- ^{94}Ag transitions were identified in the Doppler corrected γ-ray spectra for:
  - Prompt emission
  - short-lived A=94 fragments (decay within 60ms)
  - One or less charged particles
  - High energy β (E > 3 MeV)



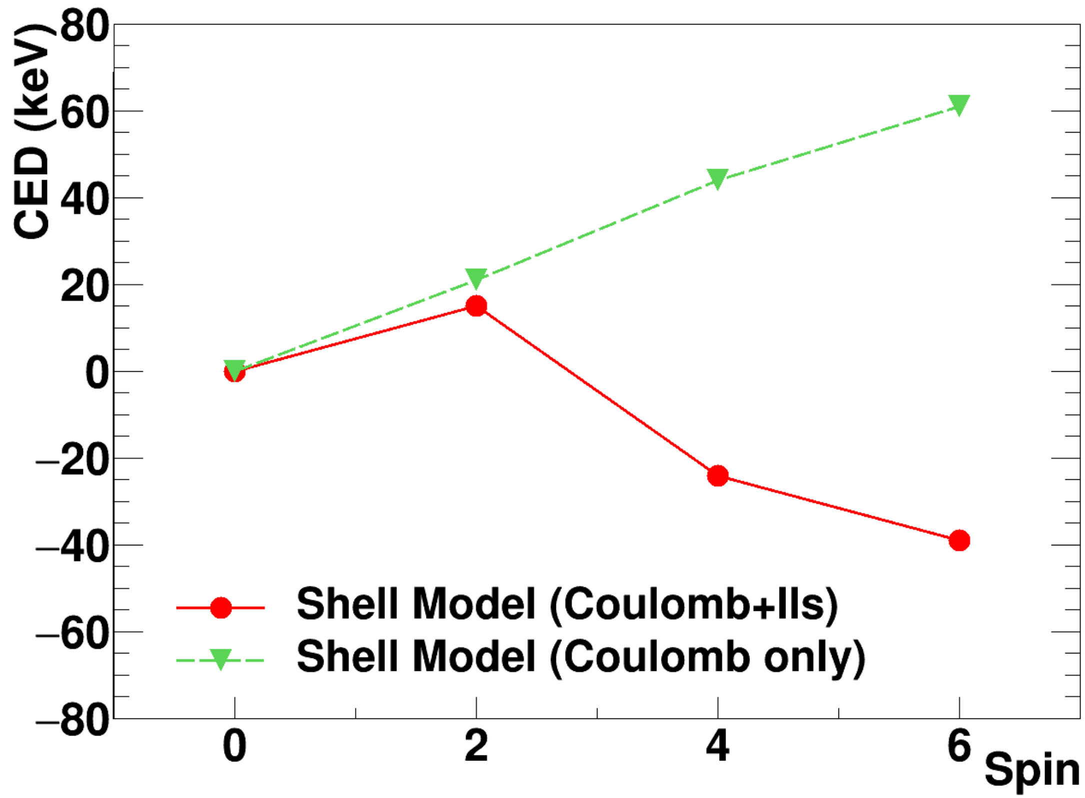
^{94}Ag transitions

Background substracted Doppler corrected spectra for prompt γ-rays for A=94 recoils decaying withing 60ms (a) or 120-180ms (b), in coincidence with a high energy β and rejecting events with 2 or more charged particles in JYtube.



CEDs

- Based on comparison with ^{94}Pd
  - 791, 874 and 637 keV in ^{94}Ag
    analog states of
  - 814, 905 and 659 keV in ^{94}Pd
- Negative CEDs
  - Observed only for ^{70}Br-^{70}Se
- Compared to SM calculations
  - JUN45, fpg model space
  - decresing trend
  - ~35 keV shift



CEDs as function of J between tentatively assigned T=1 levels in ^{94}Ag and analog states in ^{94}Pd.