Study of neutron-rich isotopes with neutron-induced-fission reactions

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Kraków 23.11.2020

Outline:

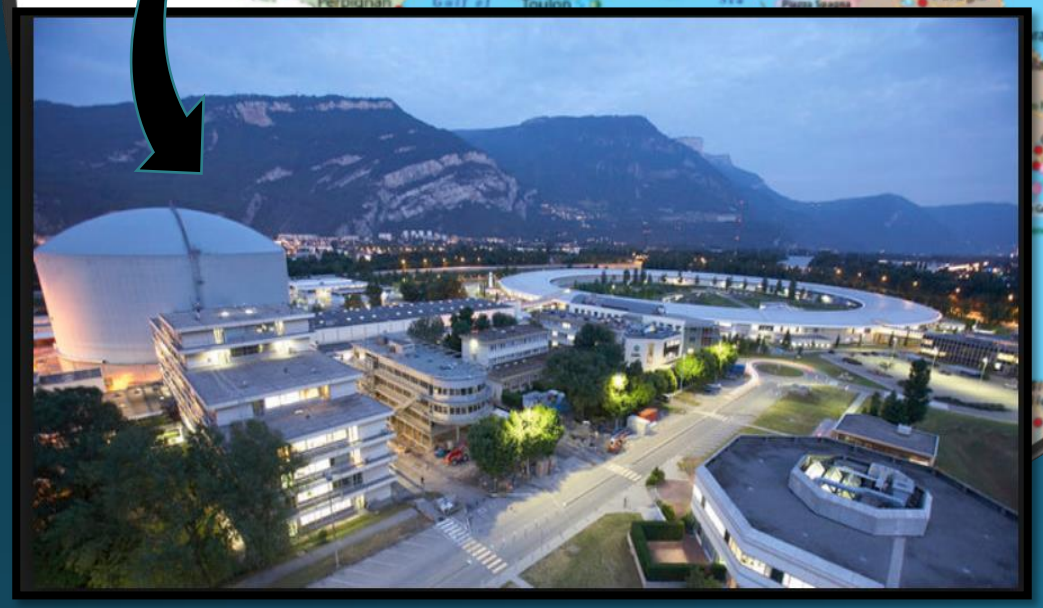
- Identification of the new level schemes in neutron-rich isotopes produced in fission reactions induced by thermal and fast neutrons

- Development of the reaction tag for fission experiments
  - Scintillator-based active target
  - Diamond- and SiC-based fission tag

- Lifetimes measurement of the states in neutron-rich isotopes by employing LOHENGRIN mass spectrometer

- Study low-spin states in ^{62}Ni via two neutrons transfer reaction

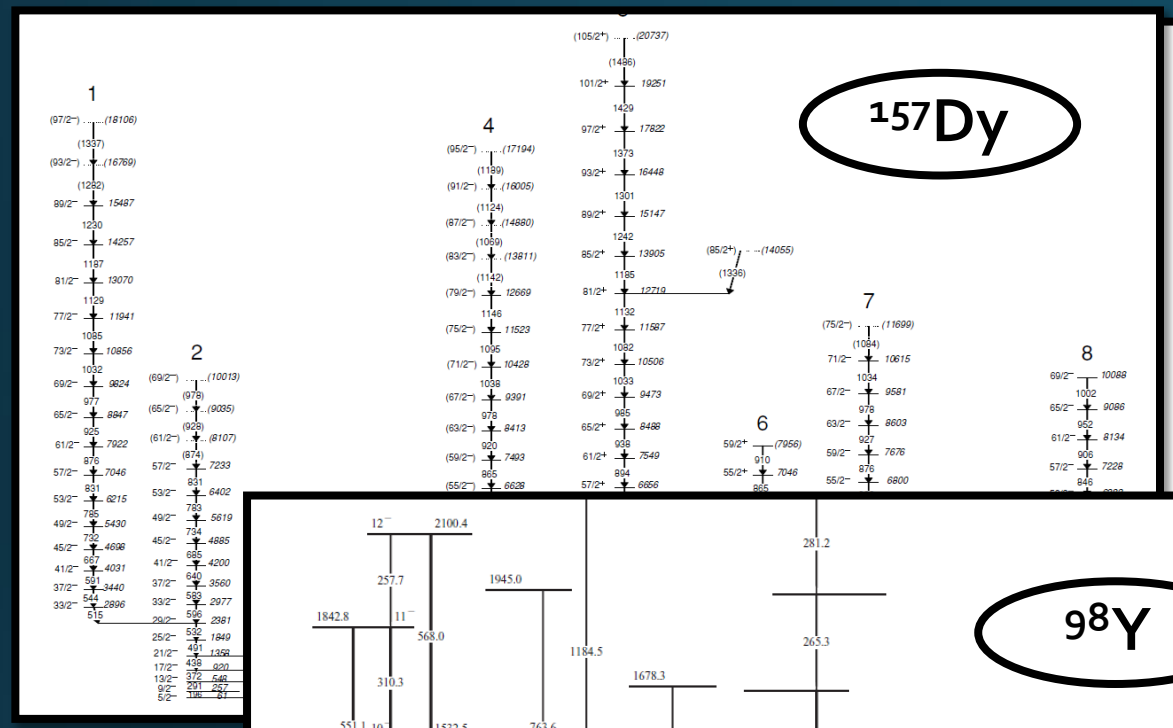
Laboratoire de Physique des 2 infinis Irène Joliot-Curie - IJCLab



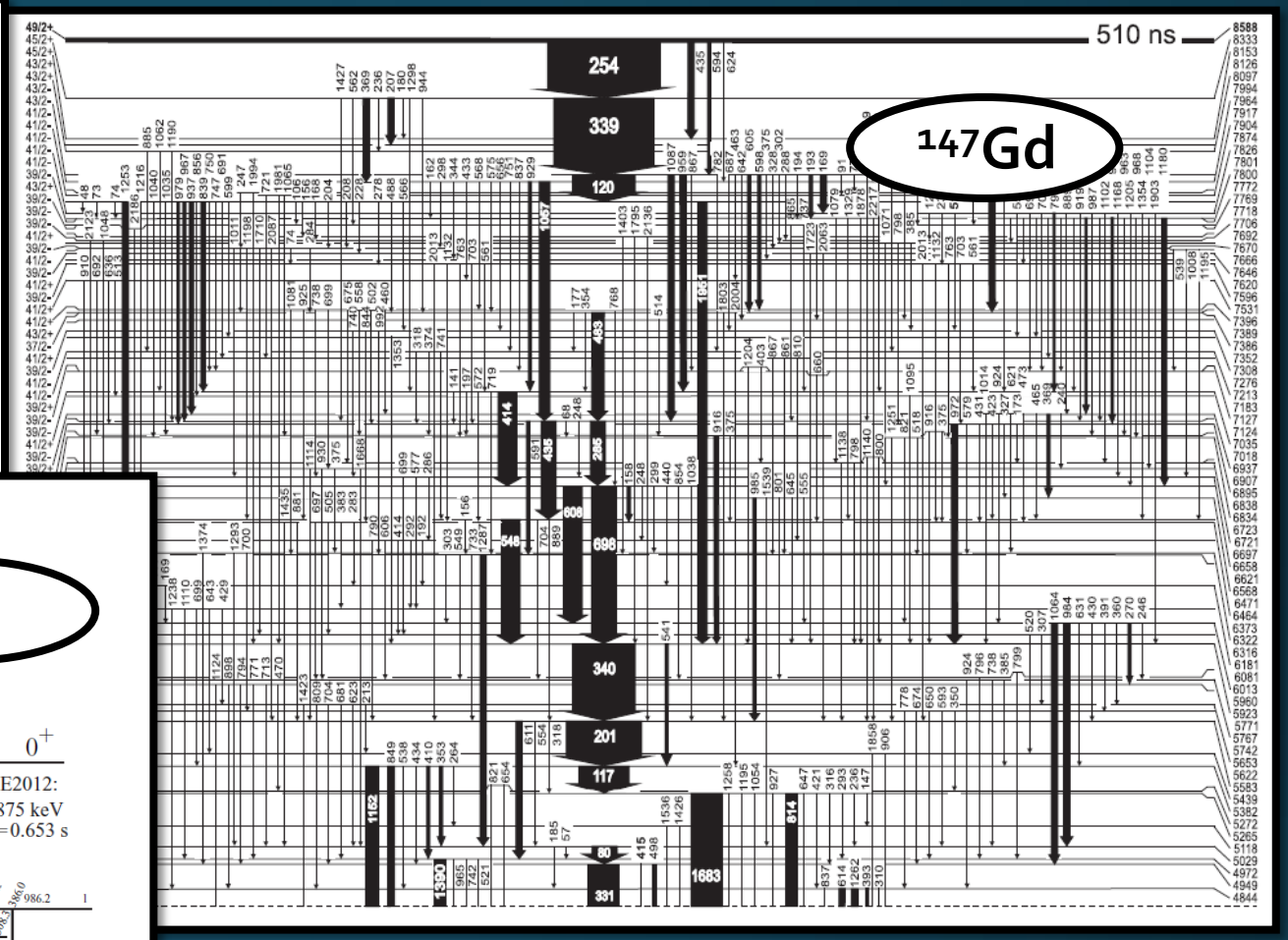
Institut Laue-Langevin - ILL

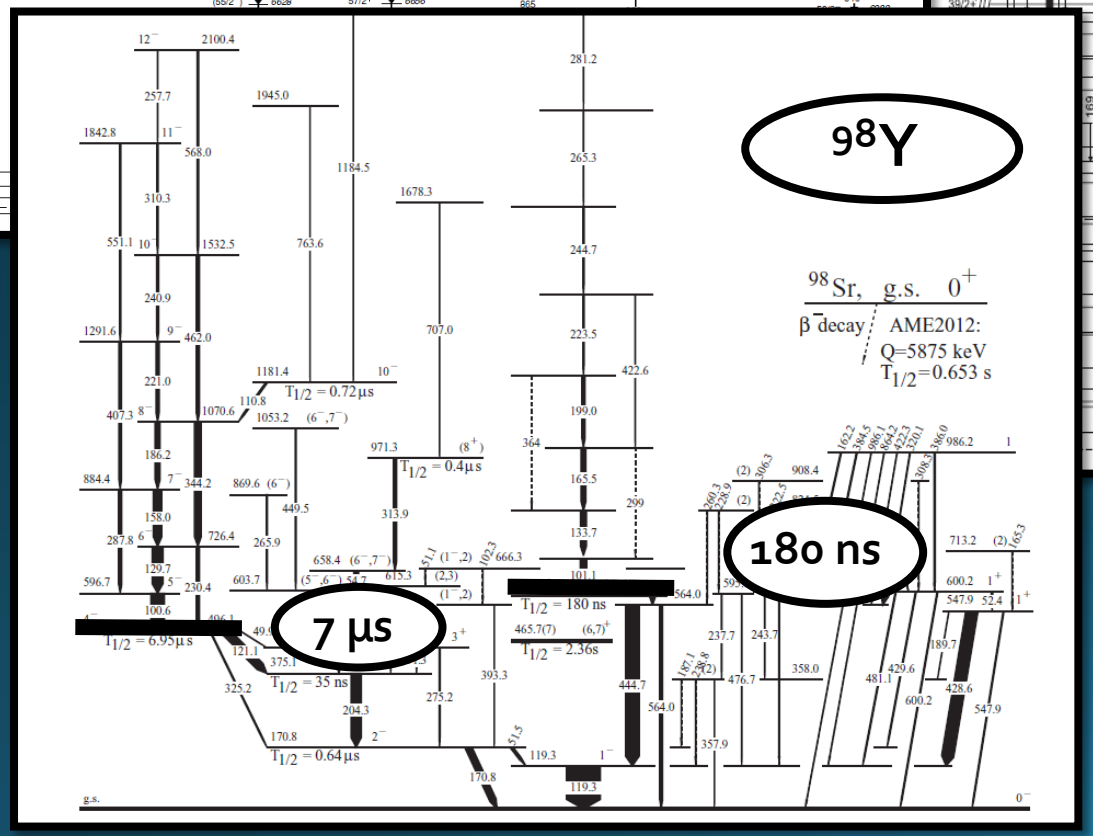
INFN sezione di Milano

A. Pipidis *et al.*, PRC **72**, 064307 (2015)



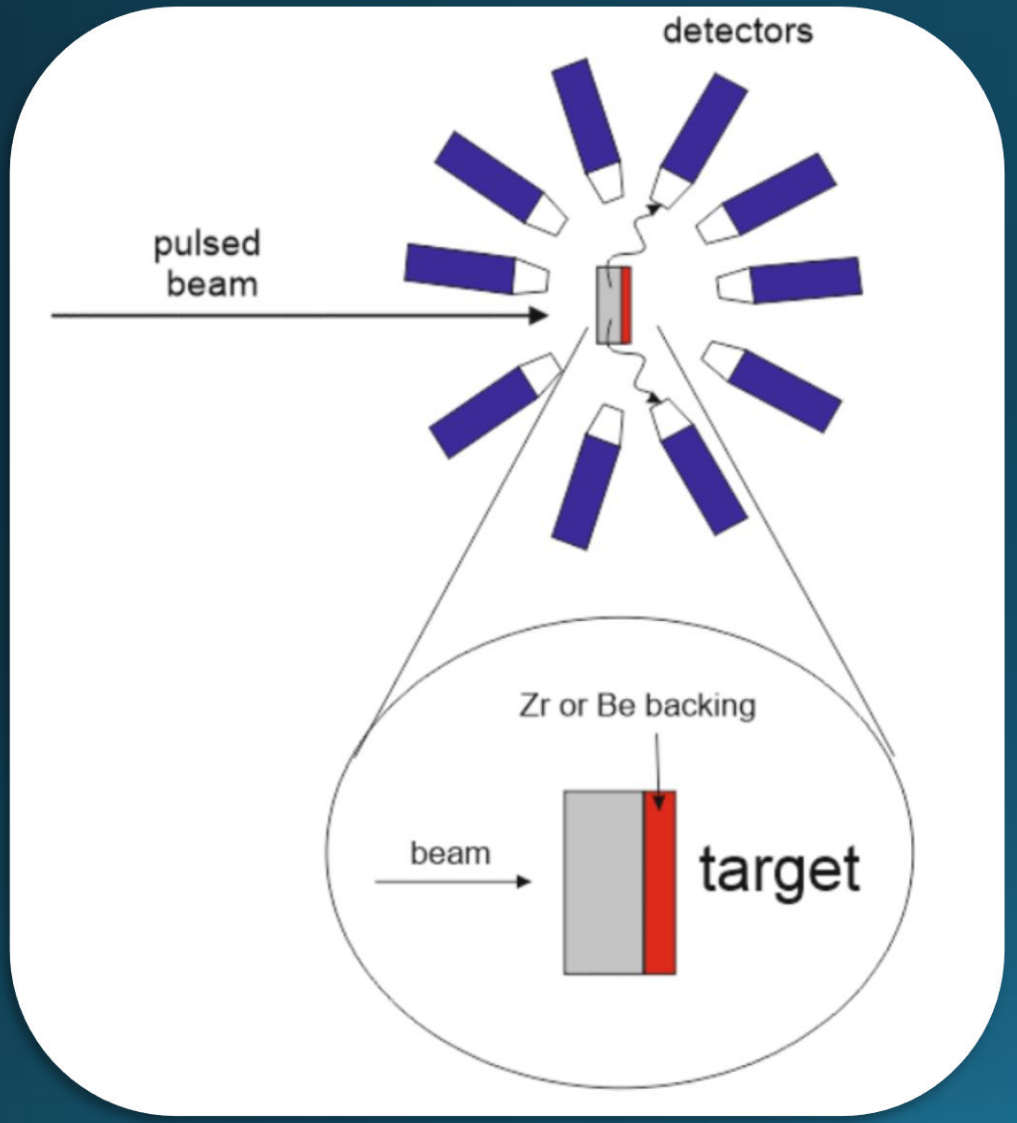
R. Broda *et al.*, PRC **72**, PRC **101**, 064320 (2020)





W. Urban (Ł.W. Iskra) et al.., PRC **96**, 044333 (2017)

Typical experimental setup and requirements



- Pulsed beam (few ns width; hundreds ns repetition time)
  - reaction tag
- Thick target (or backing) – doppler free detection
- Detectors :
  - HPGe – discrete gamma-ray spectroscopy
  - $LaBr_3$ – lifetimes measurement

v-ball campaign

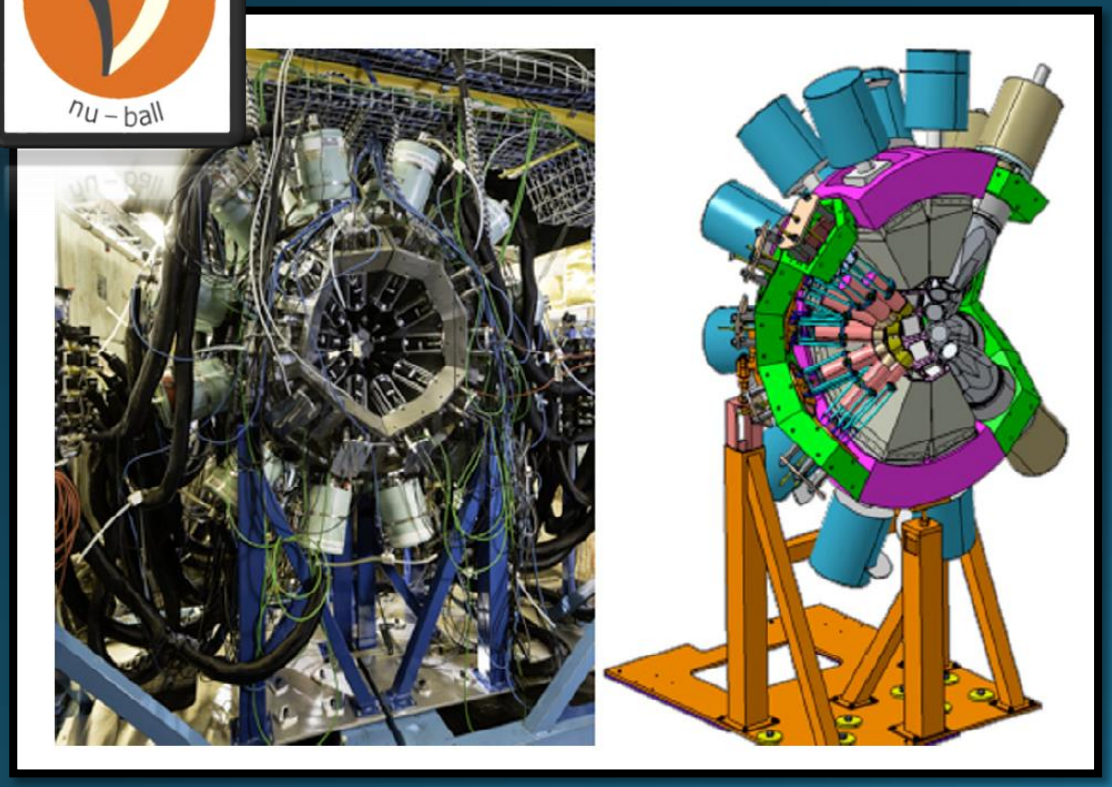
Gamma spectroscopy HPGe

- 24 clover detectors
- 10 large coaxial detectors

Lifetimes measurement

- 20 $LaBr_3$

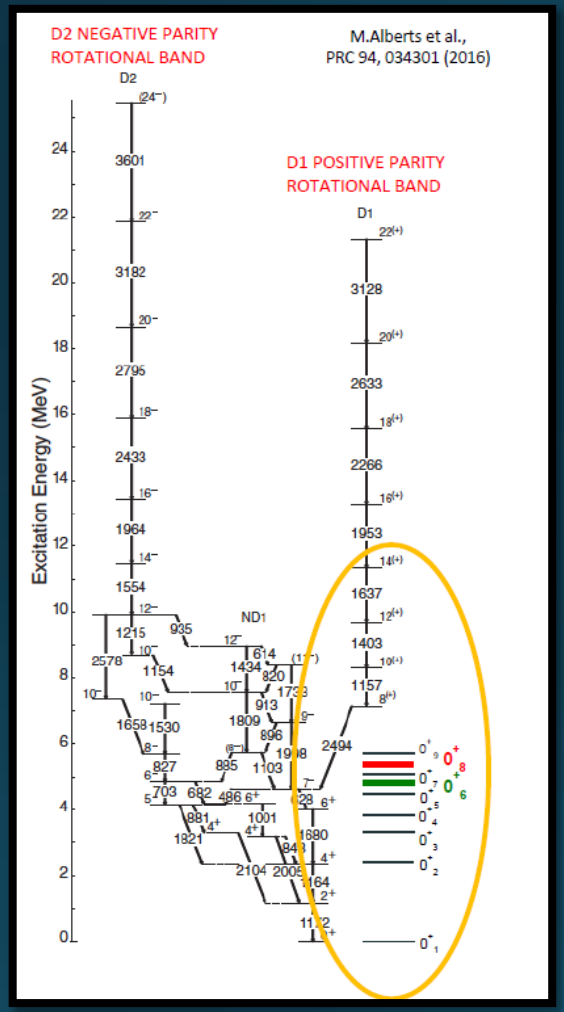
- pulsed beam with 400 ns repetition time

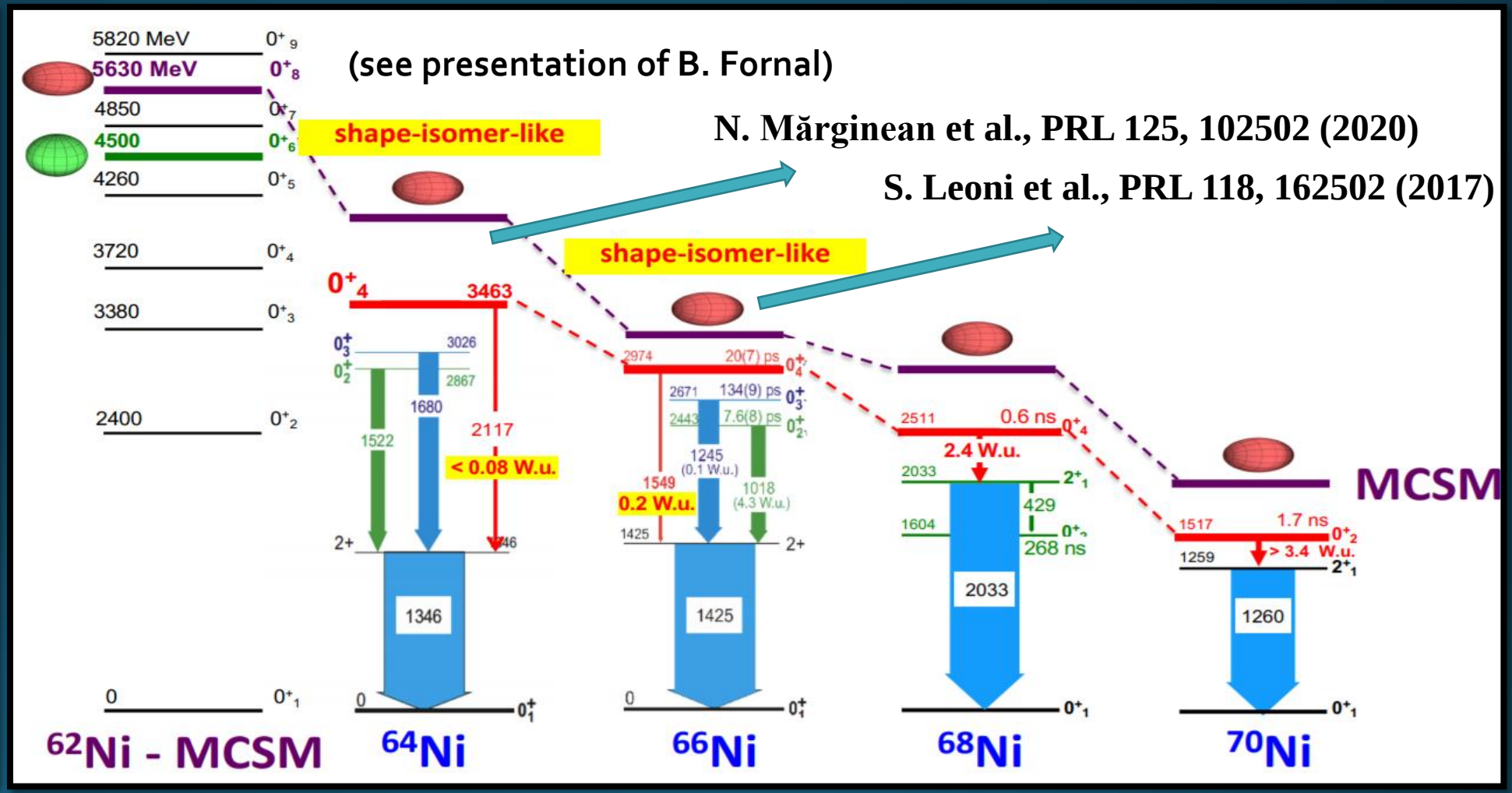


Laboratoire de Physique des 2 infinis Irène Joliot-Curie - IJCLab

Detailed Gamma Spectroscopy of ^{62}Ni: Searching for the onset of shape coexistence in neutron-rich Ni isotopes

MONTE CARLO SHELL MODEL Calculations (MCSM) - Takaharu Otsuka's Group, Univ. of Tokyo

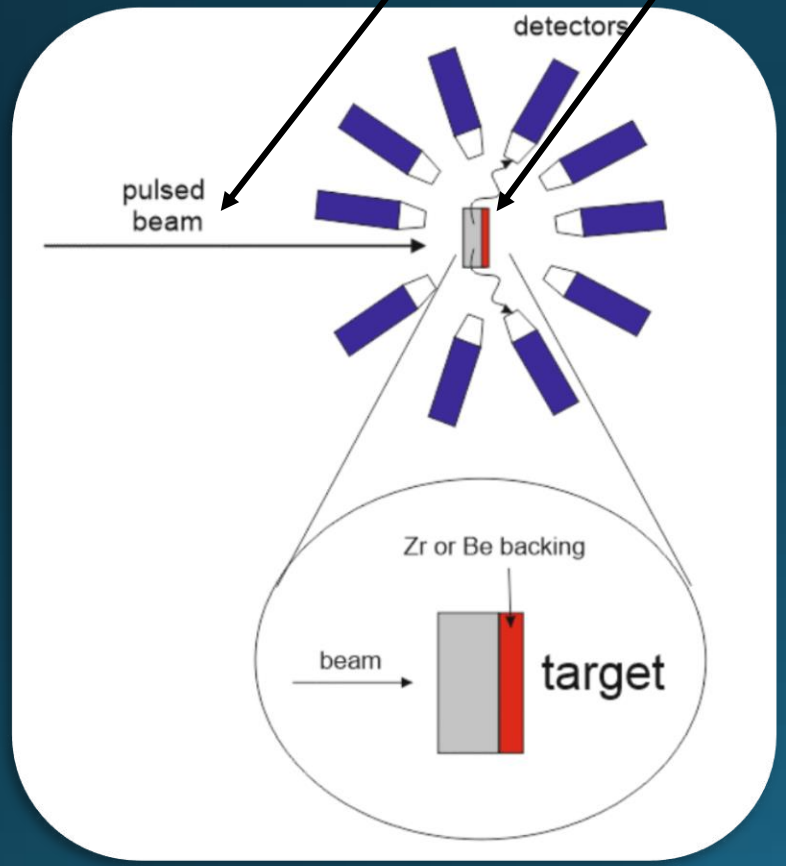




Spokespersons: S. Leoni, B. Fornal, N. Marginean

TWO NEUTRONS TRANSFER REACTION

$$^{18}O + ^{60}Ni \rightarrow ^{16}O + ^{62}Ni$$

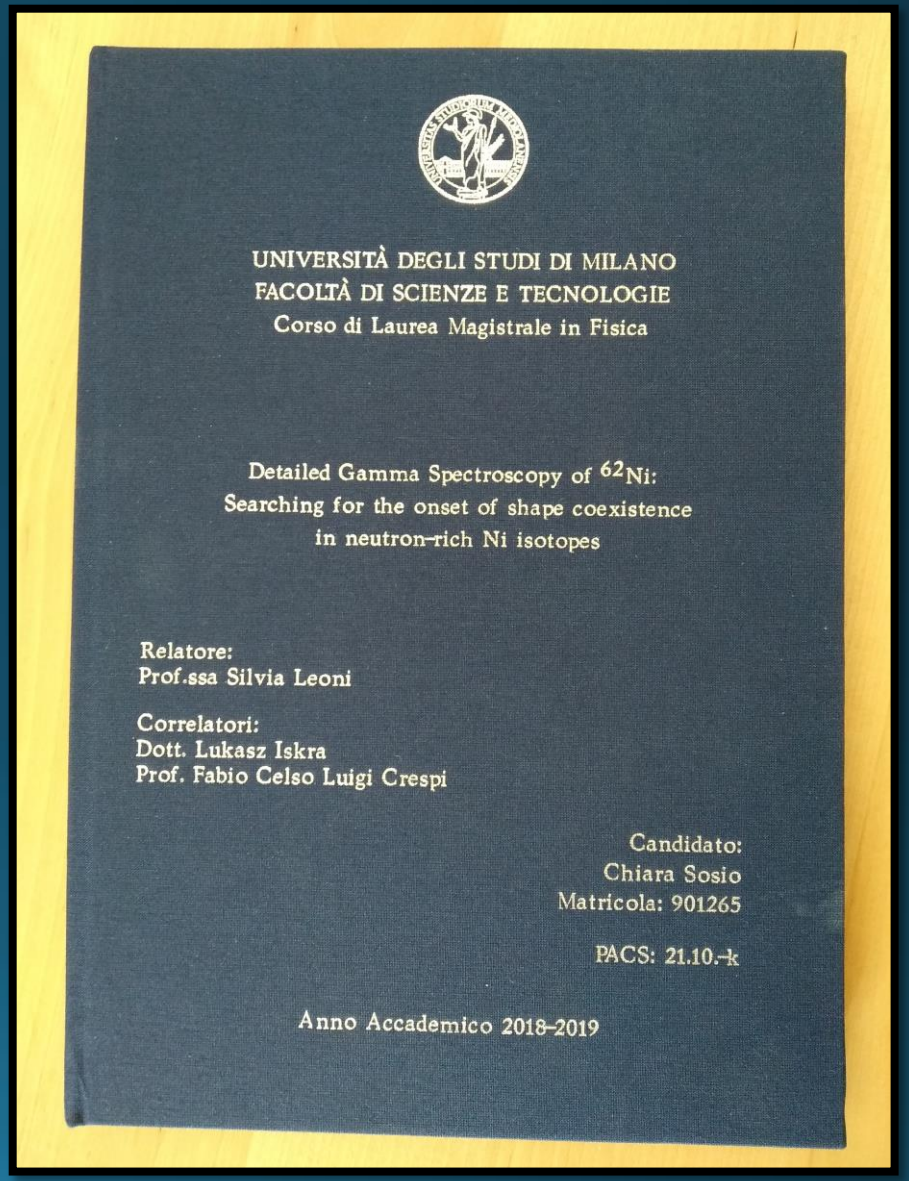


Beam Energy:
43 MeV

Below Coulomb barrier

Target thickness:
5 mg/cm²

v-ball array
covering 75% of solid angle



UNIVERSITÀ DEGLI STUDI DI MILANO
FACOLTÀ DI SCIENZE E TECNOLOGIE
Corso di Laurea Magistrale in Fisica

Detailed Gamma Spectroscopy of ^{62}Ni:
Searching for the onset of shape coexistence
in neutron-rich Ni isotopes

Relatore:
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Correlatori:
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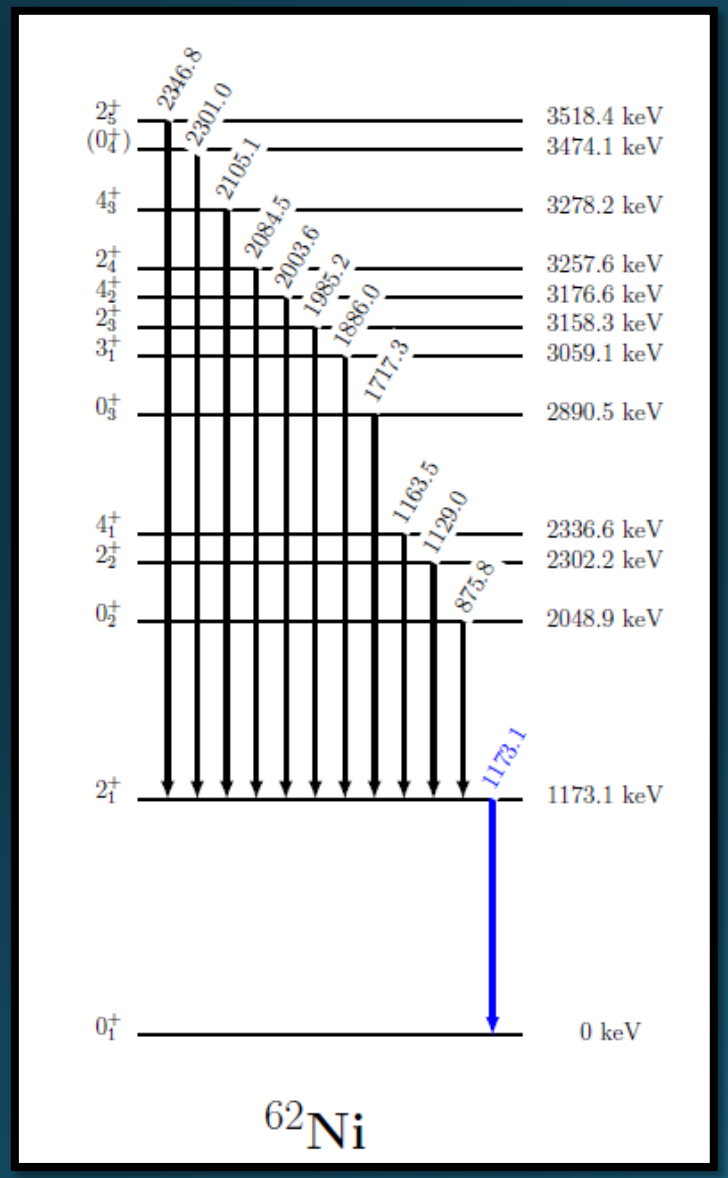
Prof. Fabio Celso Luigi Crespi

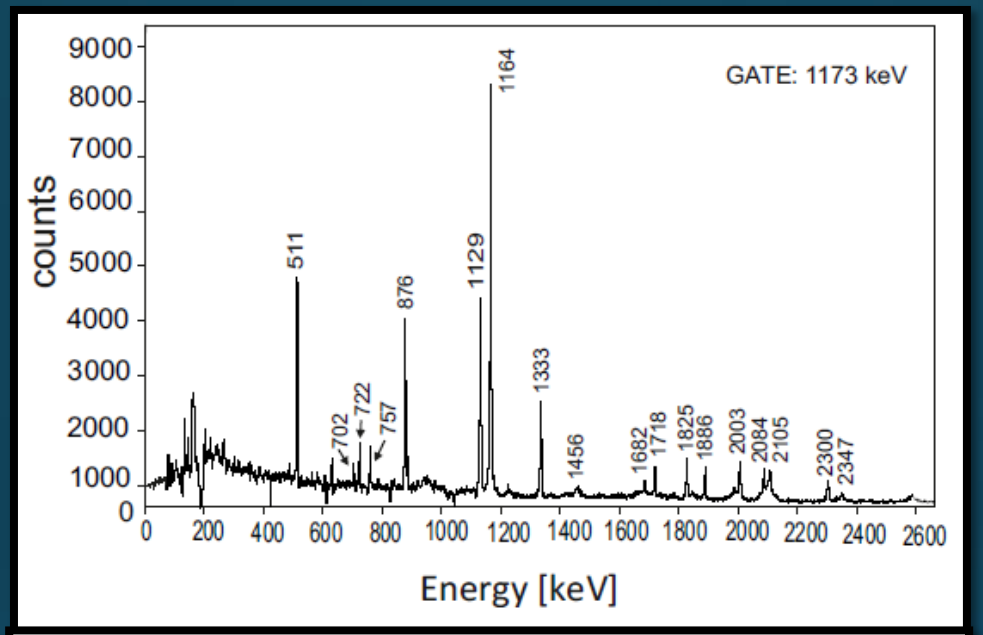
Candidato:
Chiara Sosio
Matricola: 901265

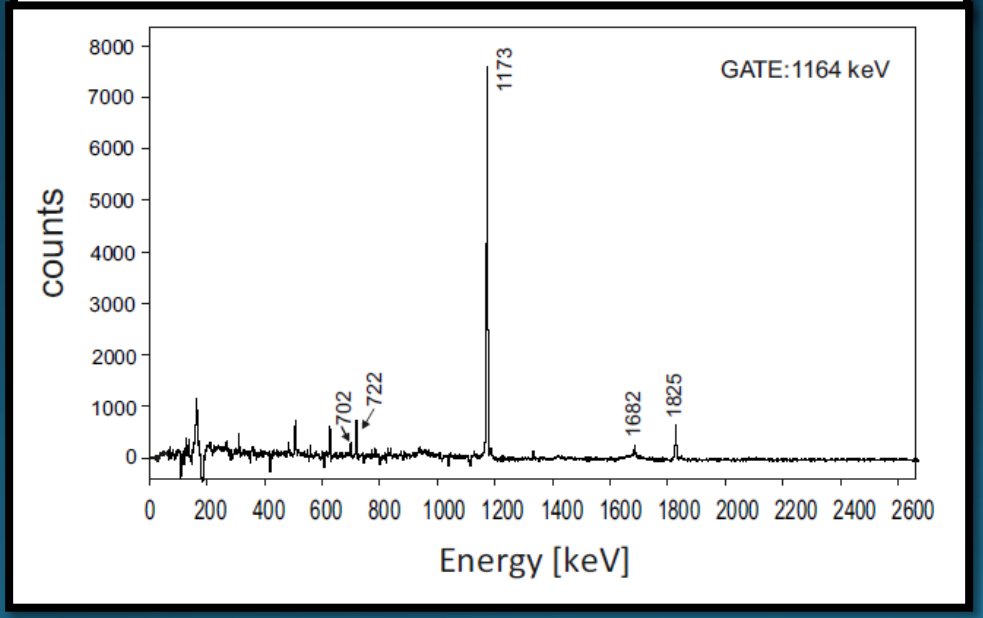
PACS: 21.10.-k

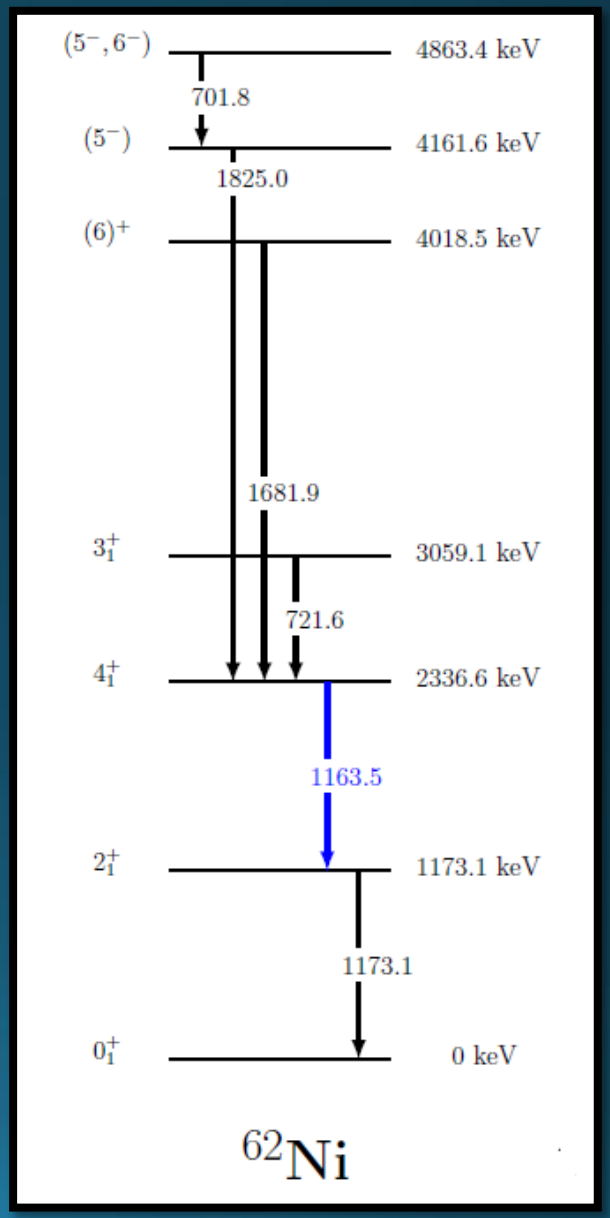
Anno Accademico 2018-2019

Gamma coincidence technique

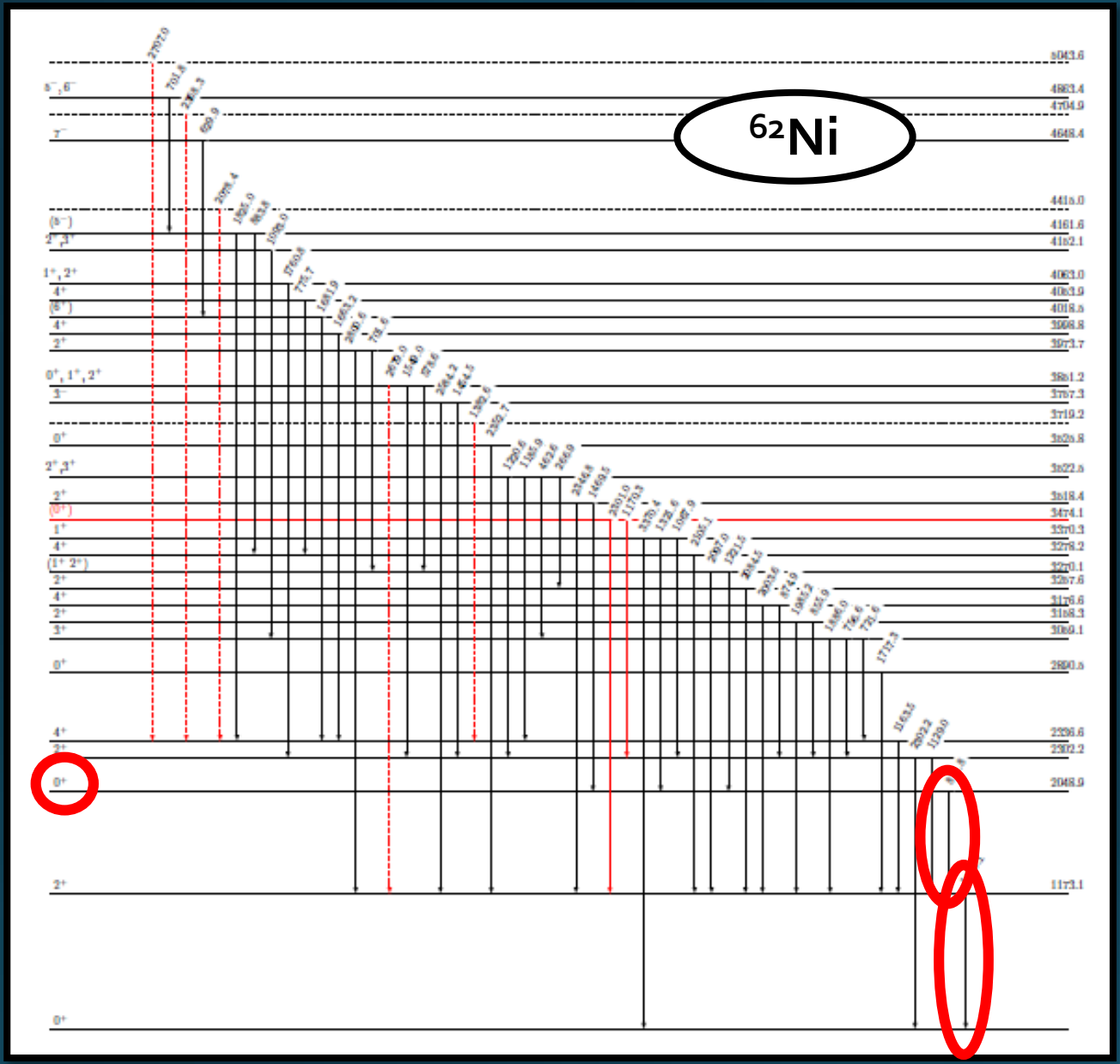


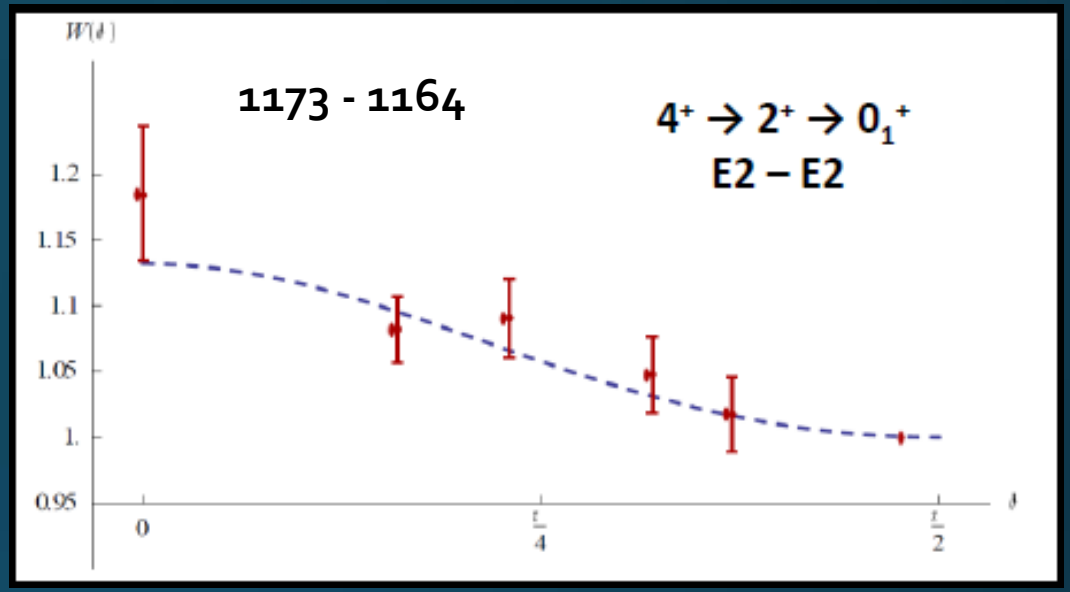


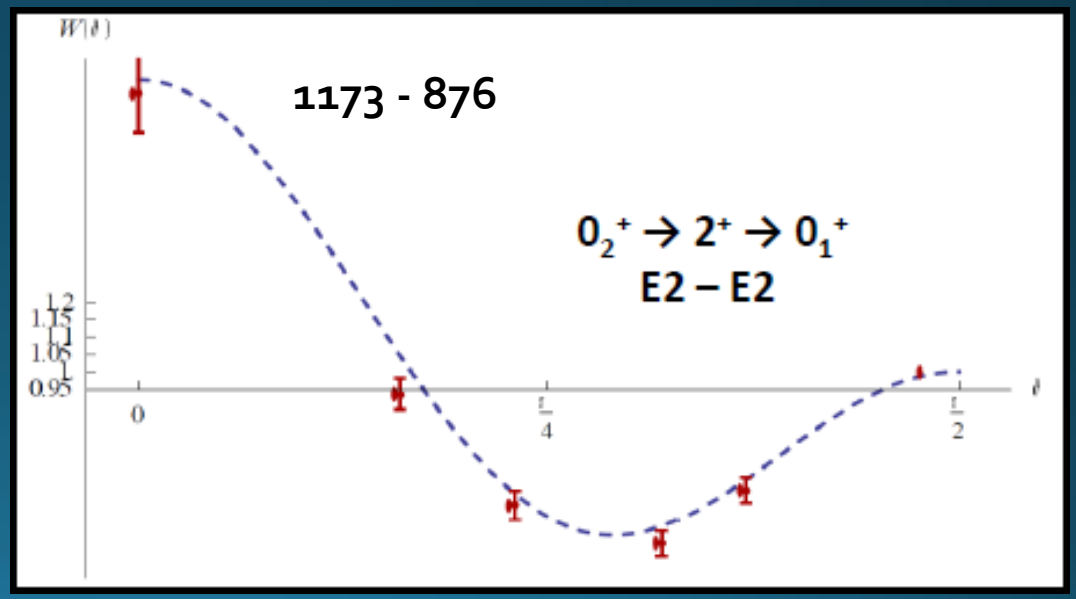




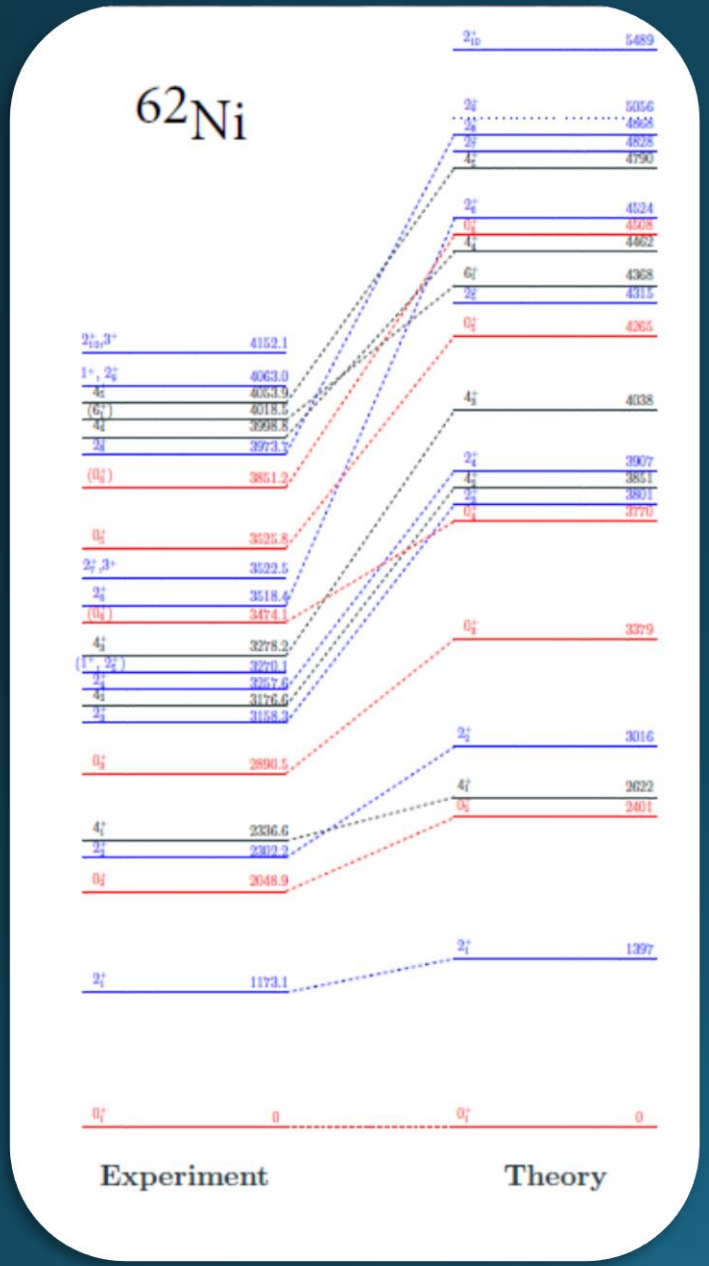
Gamma coincidence technique

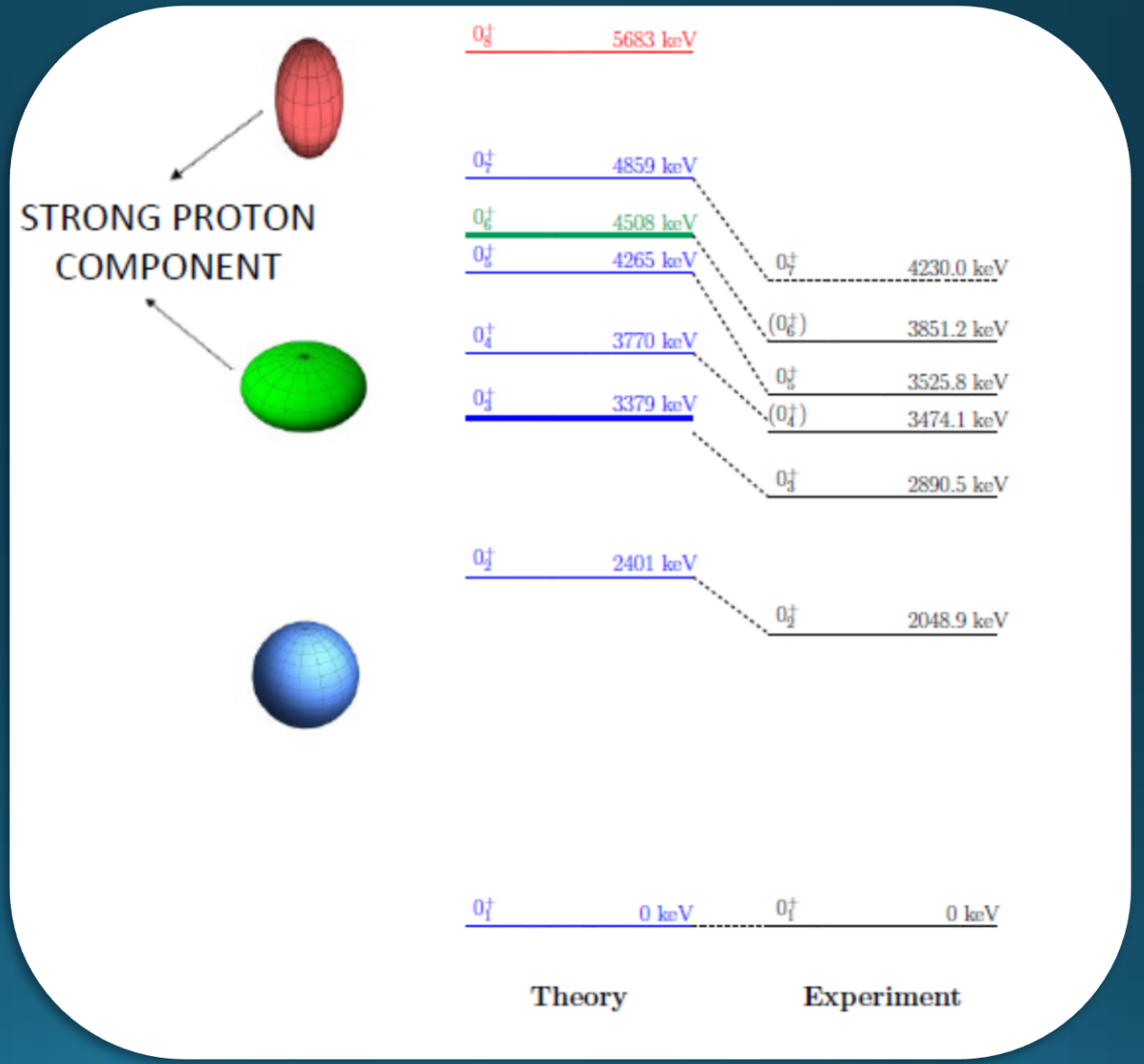






Comparison between experiment and theory





Comparison between two neutrons transfer and one proton transfer

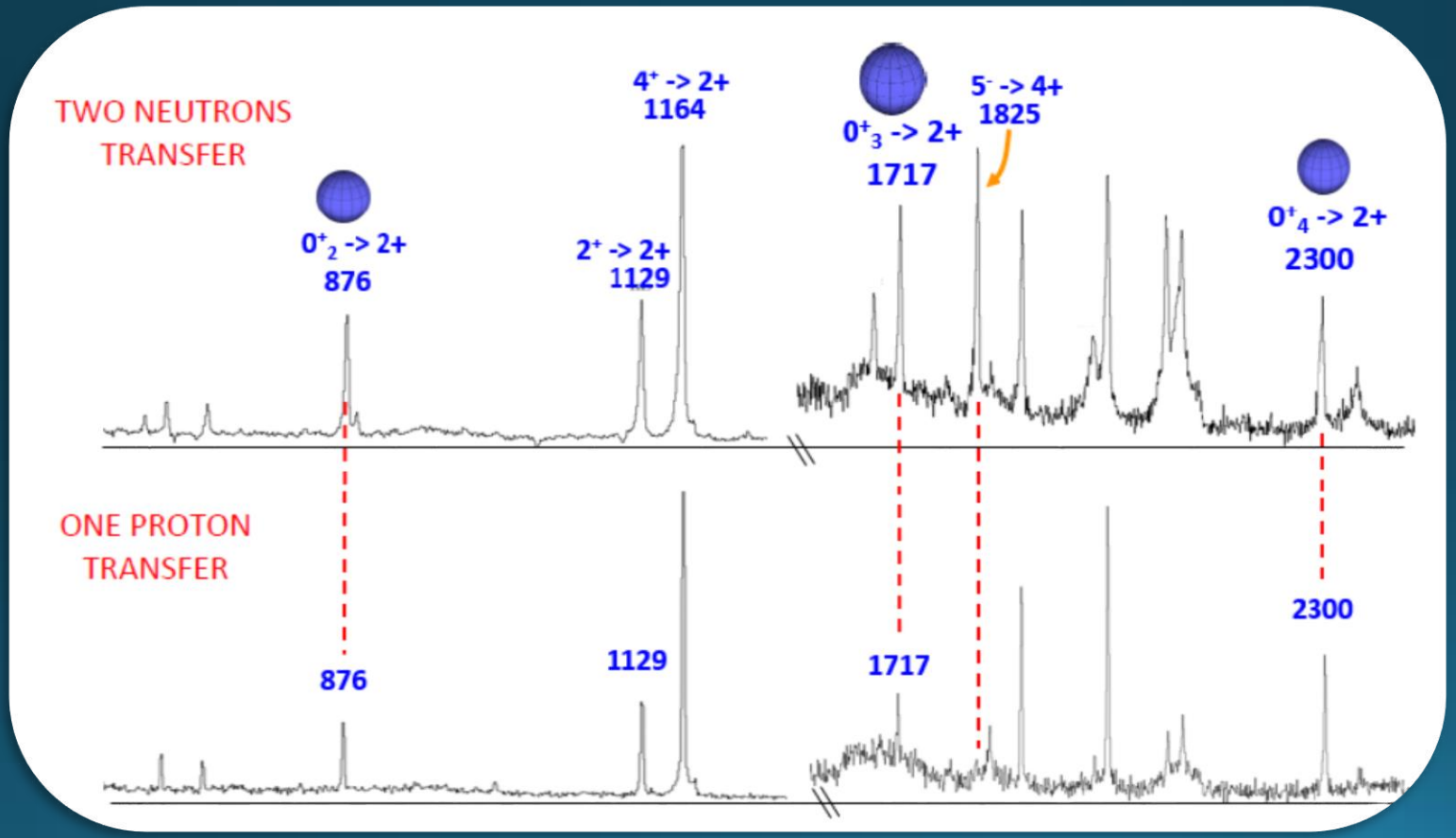
IFIN-HH laboratory (Romania) - ROSPHERE array: 25 HPGe

ONE PROTON TRANSFER REACTION

$^{11}B + {}^{63}Cu \longrightarrow {}^{12}C + {}^{62}Ni$

Thickness of the target: 5 mg/cm^2

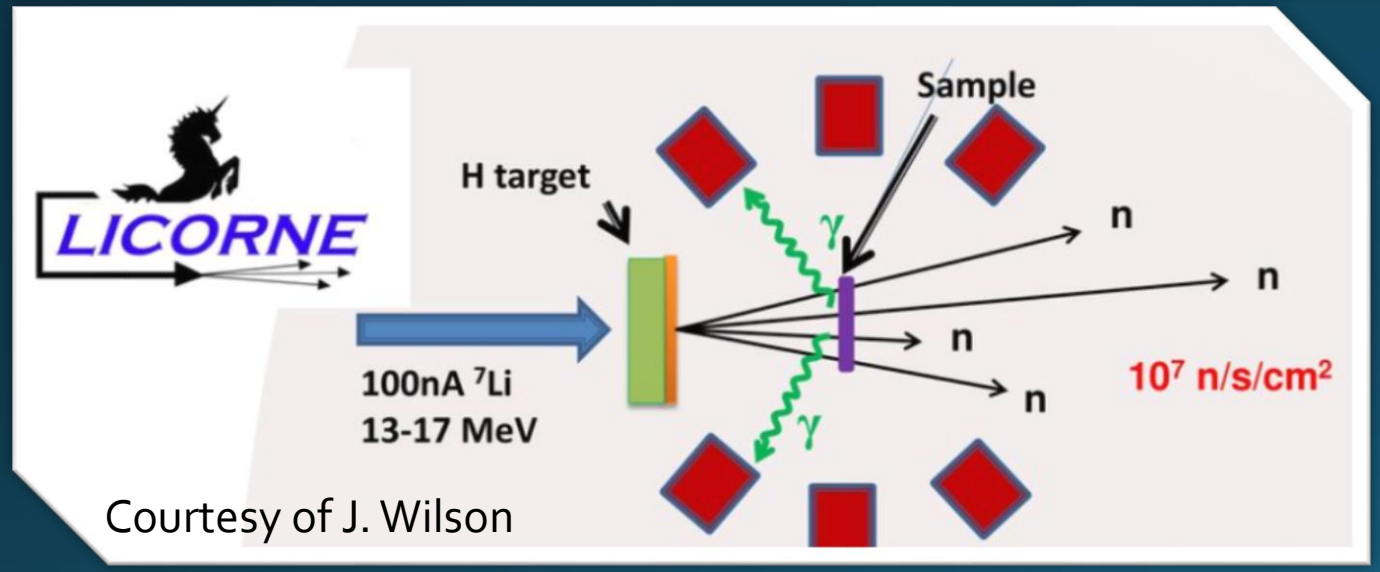
E_{beam} = 24 MeV (sub-Coulomb barrier reaction)



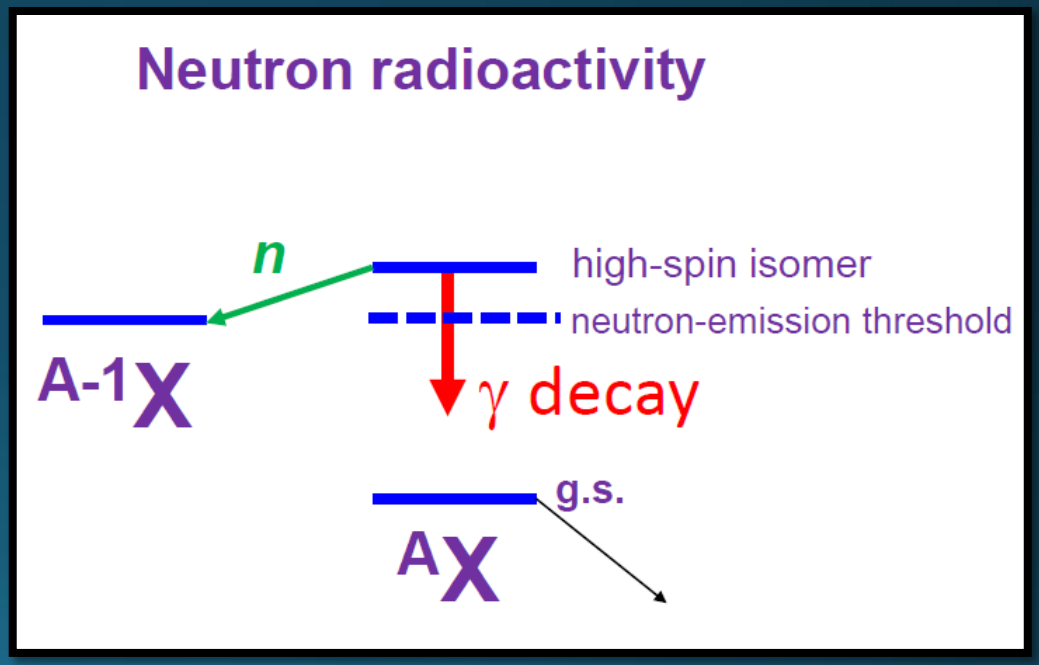
Study of neutron-rich isotopes with neutron-induced-fission reactions

7) v-ball/LICORNE Physics Case: Gamma spectroscopy in the north-east region of doubly magic ^{78}Ni – search for neutron radioactivity

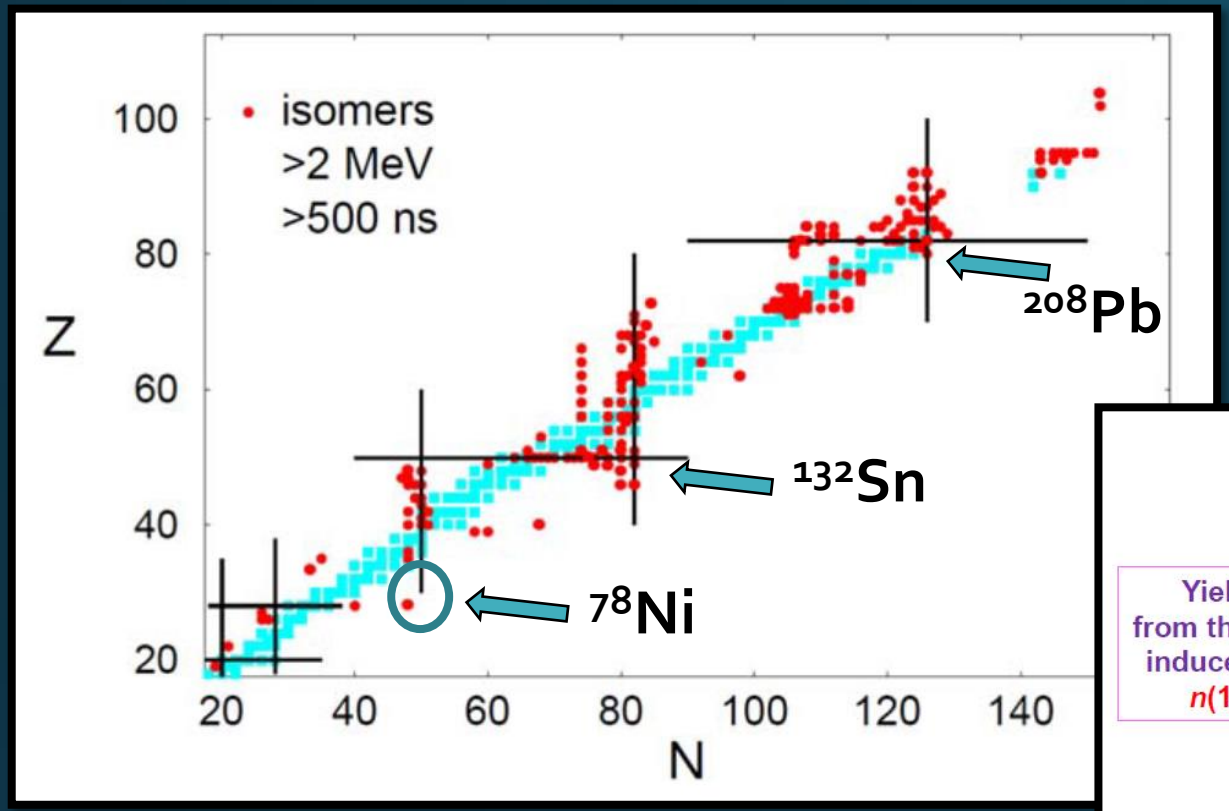
Ł. W. Iskra, B. Fornal (IFJ Krakow) and S. Leoni (University of Milano)



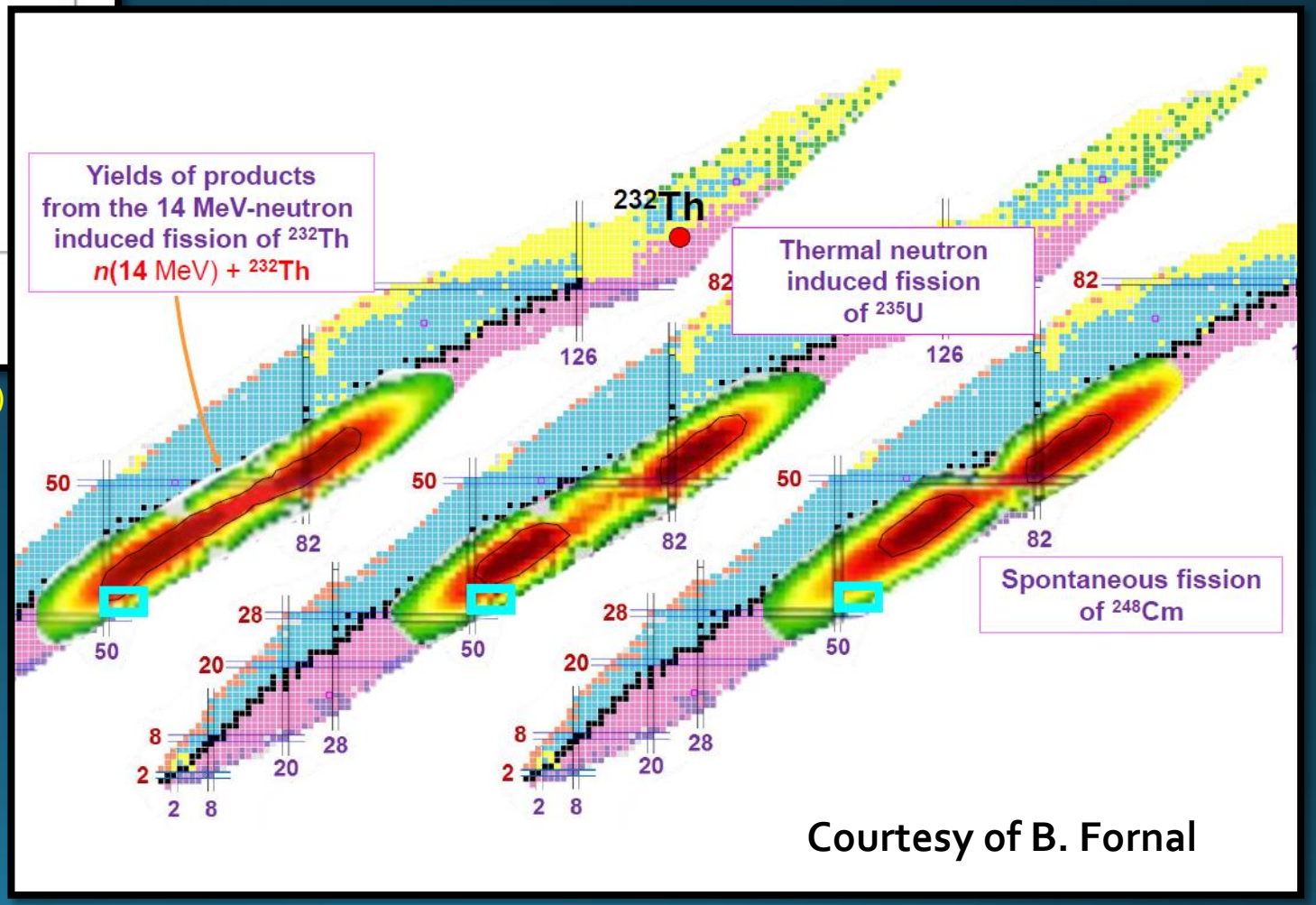
Courtesy of J. Wilson



L.K. Peker et al., Phys. Lett. B36 (1971) 547.



Philip Walker and Zsolt Podolyák, Phys. Scr.95, 044004 (2020)



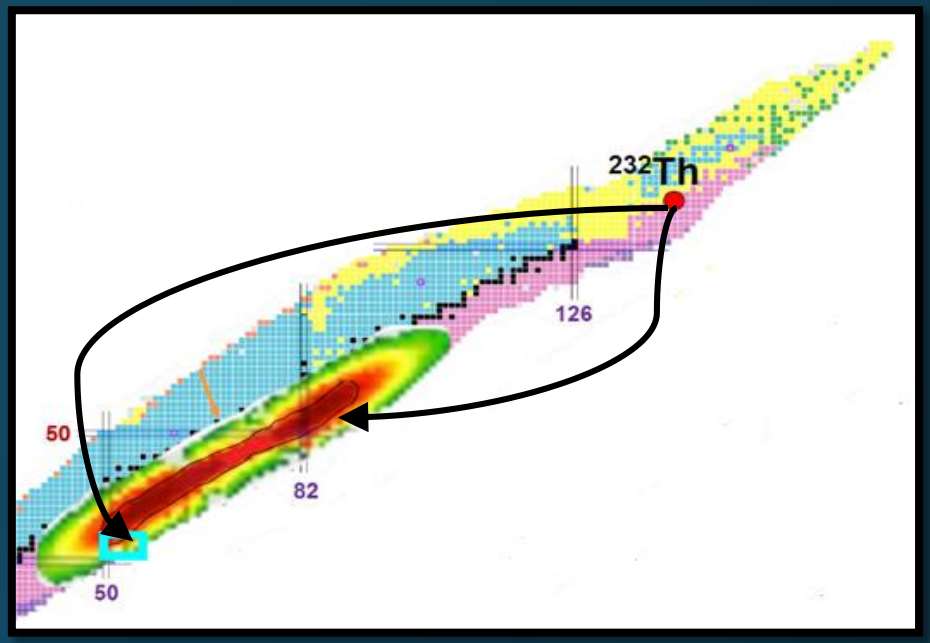
Courtesy of B. Fornal

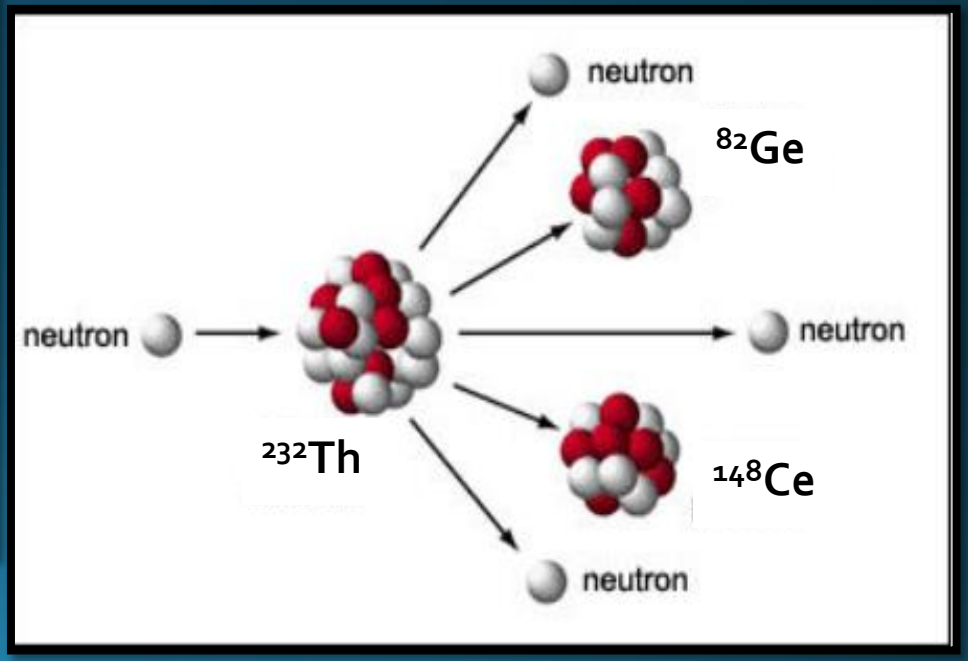
Study of the ^{82}Ge isotope

N = 50

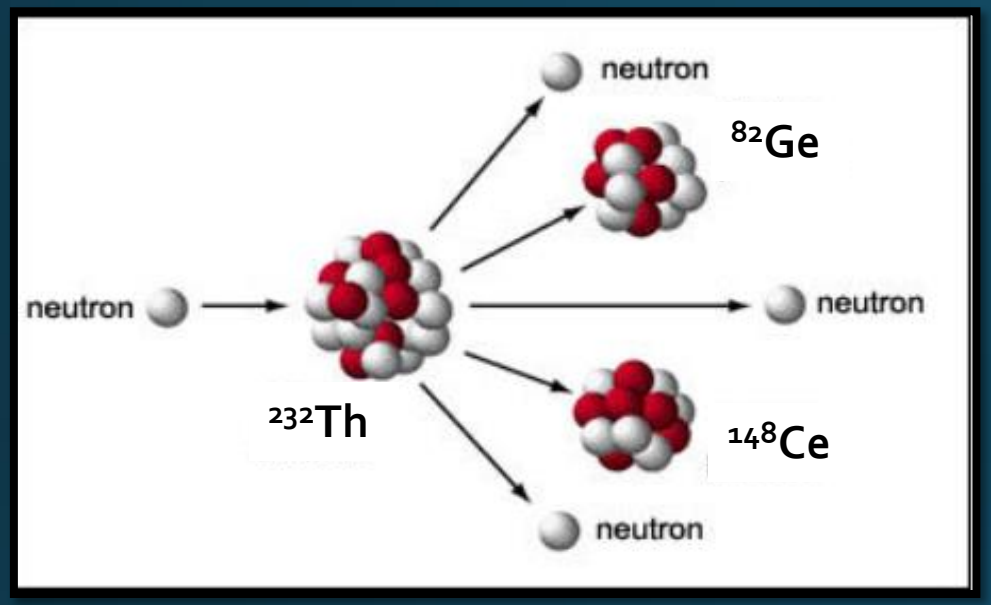
Z = 28

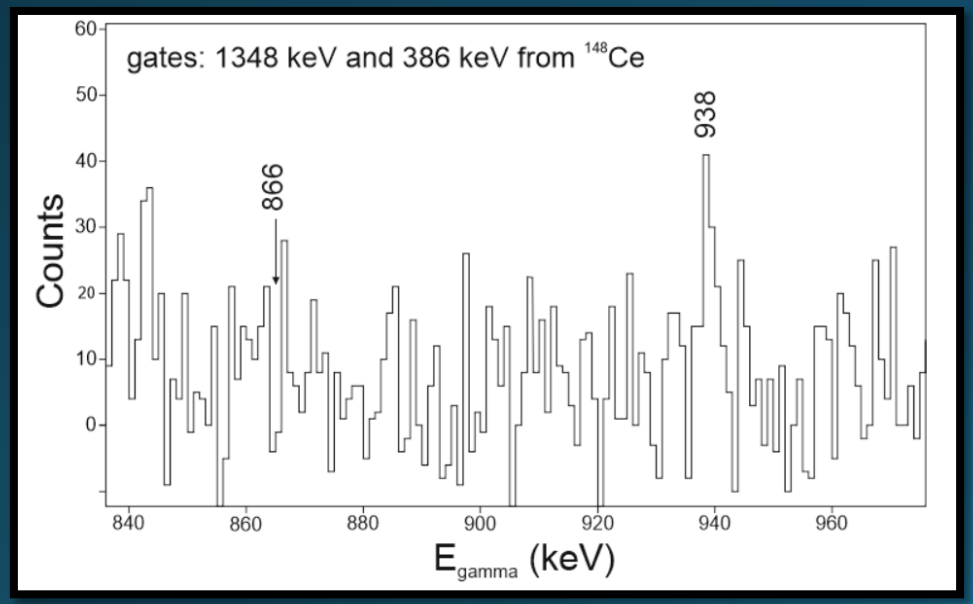
77As	78As	79As	80As	81As	82As	83As	84As	85As	86As	87As	88As
76Ge	77Ge	78Ge	79Ge	80Ge	81Ge	82Ge	83Ge	84Ge	85Ge	86Ge	87Ge
75Ga	76Ga	77Ga	78Ga	79Ga	80Ga	81Ga	82Ga	83Ga	84Ga	85Ga	86Ga
74Zn	75Zn	76Zn	77Zn	78Zn	79Zn	80Zn	81Zn	82Zn	83Zn	84Zn	85Zn
73Cu	74Cu	75Cu	76Cu	77Cu	78Cu	79Cu	80Cu	81Cu	82Cu		
72Ni	73Ni	74Ni	75Ni	76Ni	77Ni	78Ni	79Ni	80Ni			
71Co	72Co	73Co	74Co	75Co	76Co	77Co					



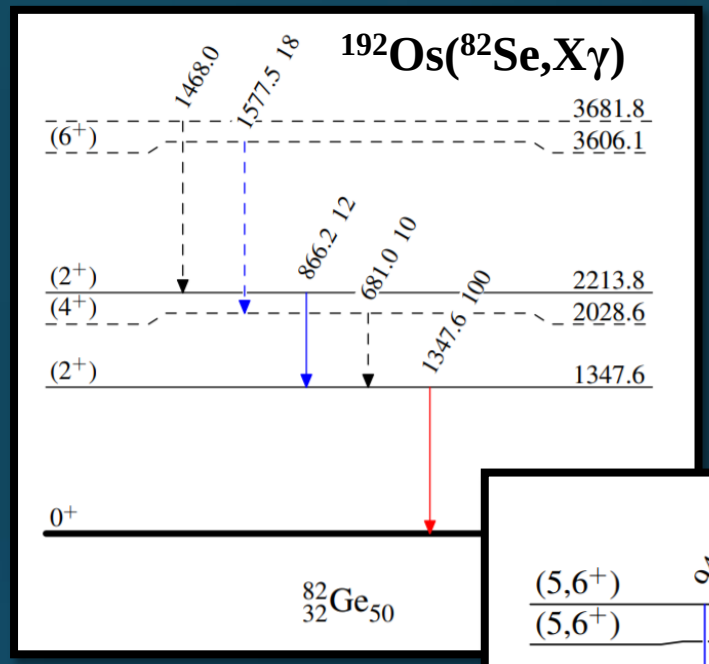


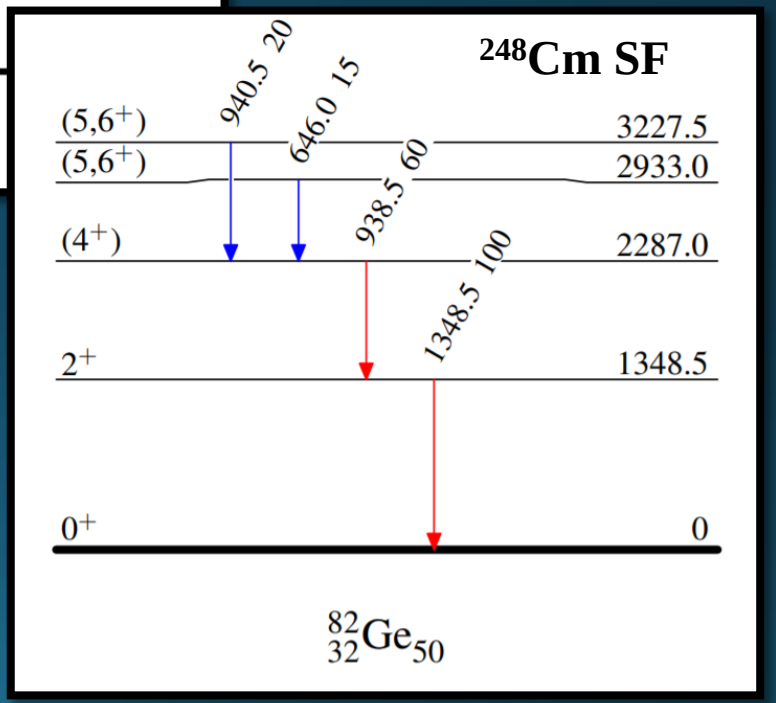
Study of the ^{82}Ge isotope





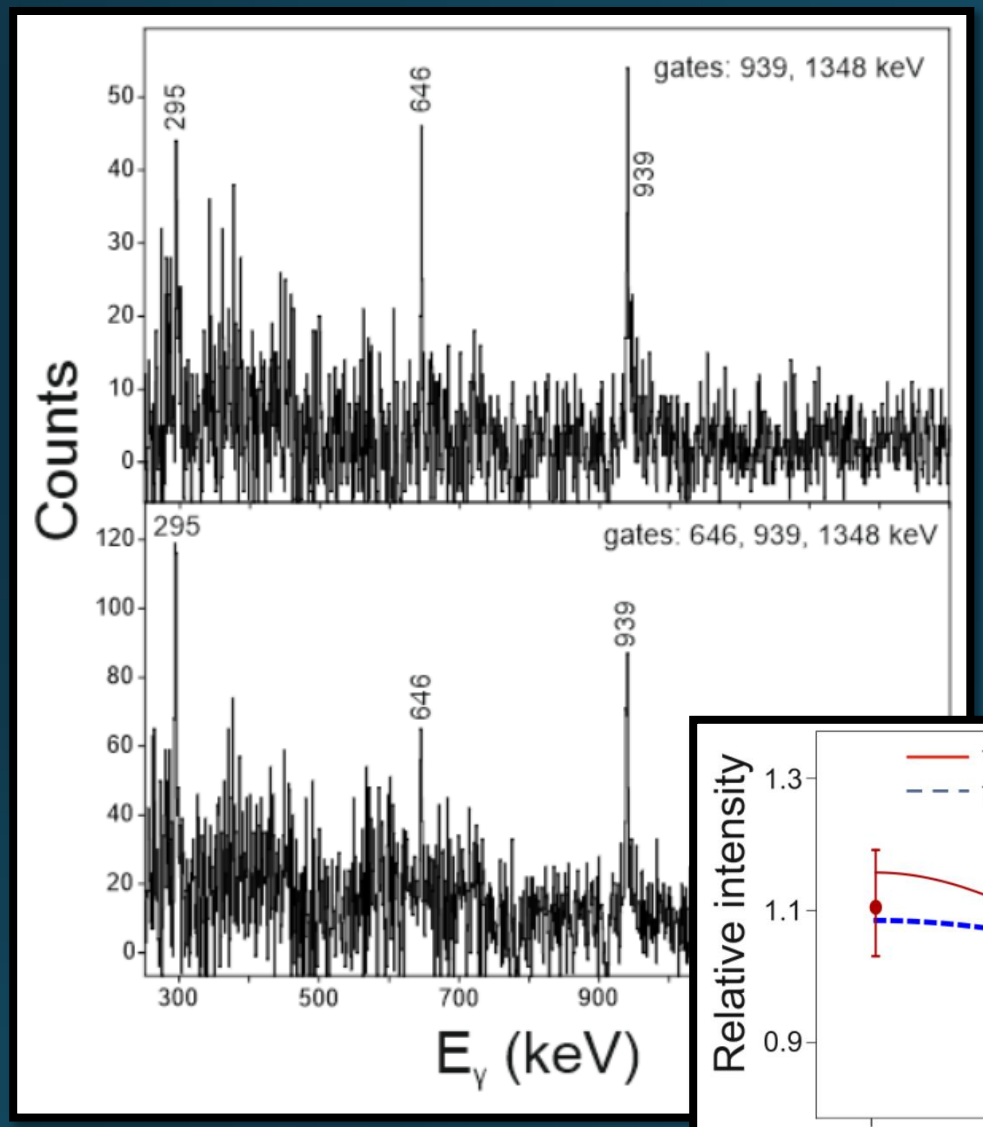
Y. H. Zhang *et al.*, Phys. Rev. C **70**, 024301 (2004)

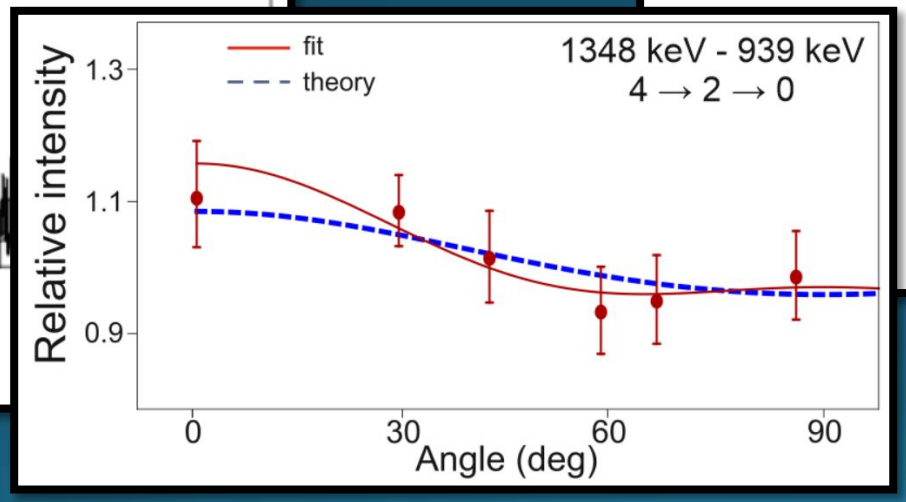


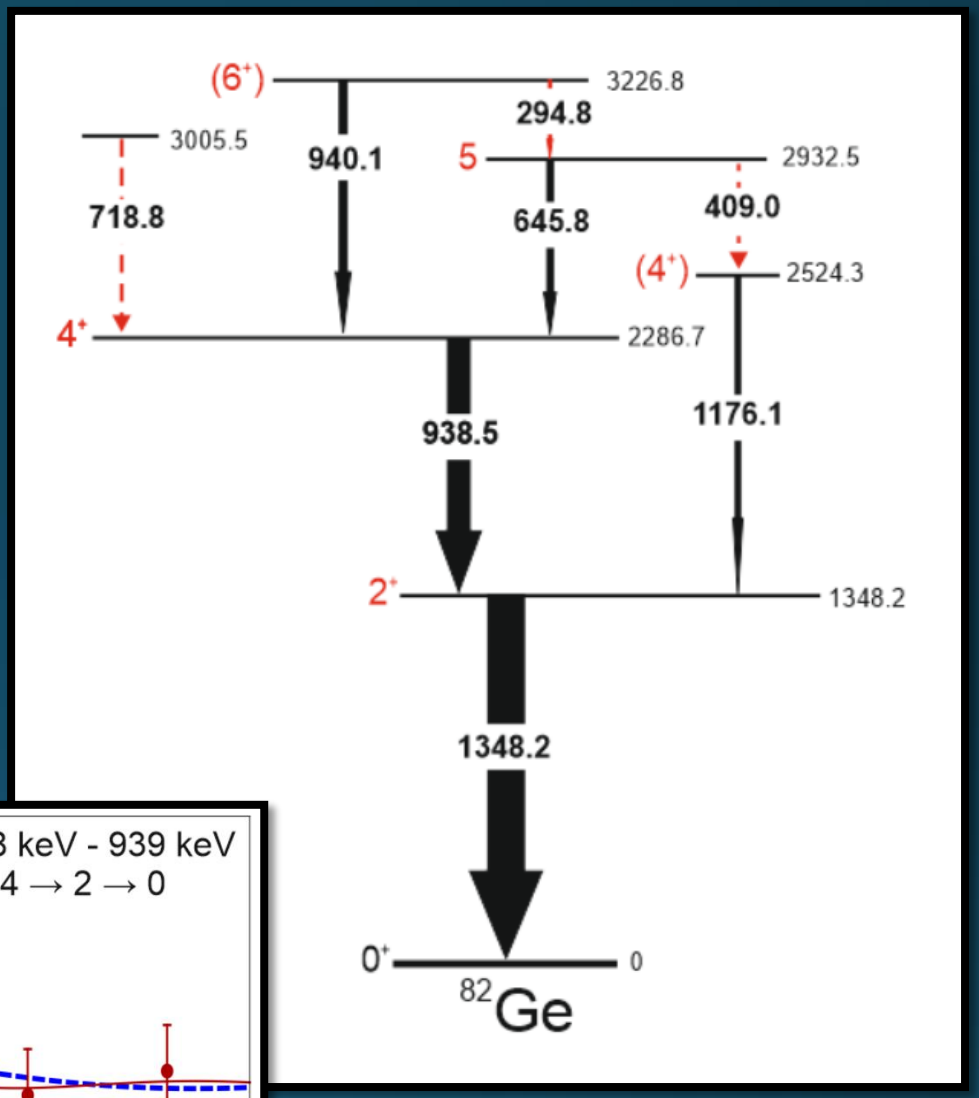


T. Rząca-Urban et al., Phys. Rev. C **76**, 027302 (2007)

Study of the ^{82}Ge isotope

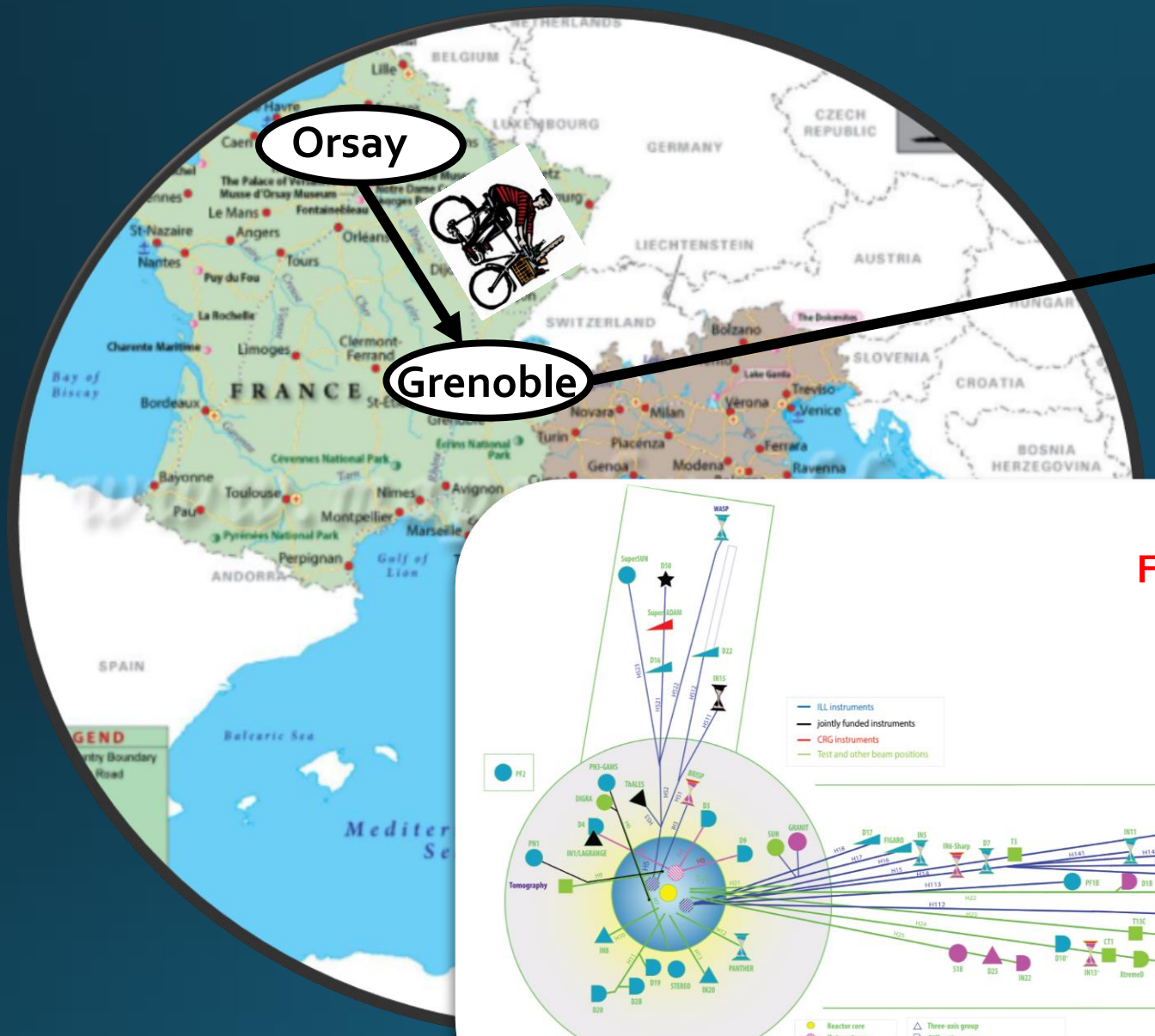


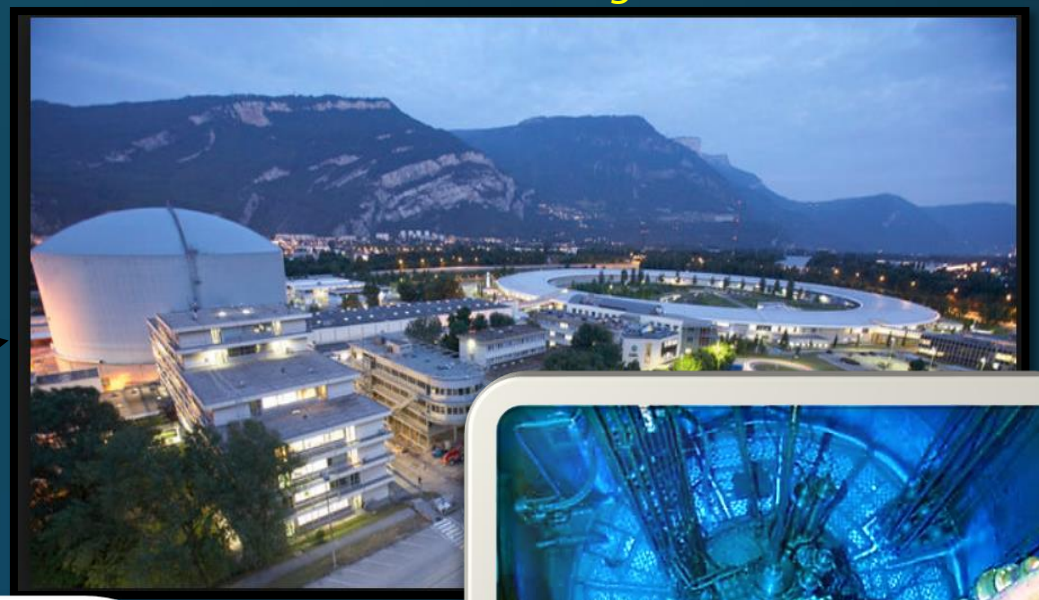


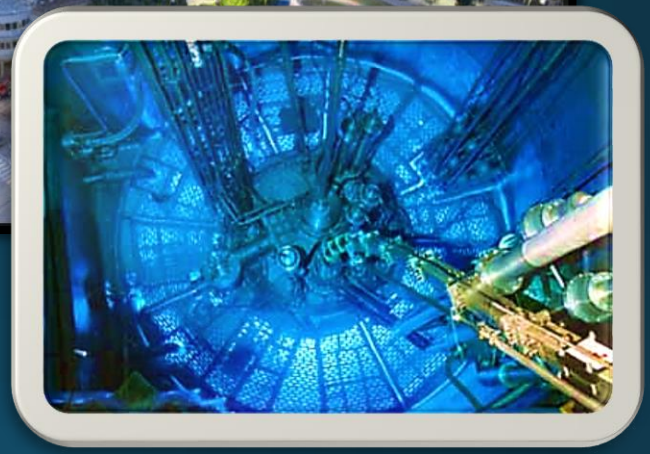


Analysis in progress …

Institut Laue-Langevin - ILL







ILL reactor – 55 MW

Most intense continuous neutron flux in the world – 1.5×10^{15} n s^{-1} cm^{-2}

$\sim 10^{8}$ n s^{-1} cm^{-2} at target position

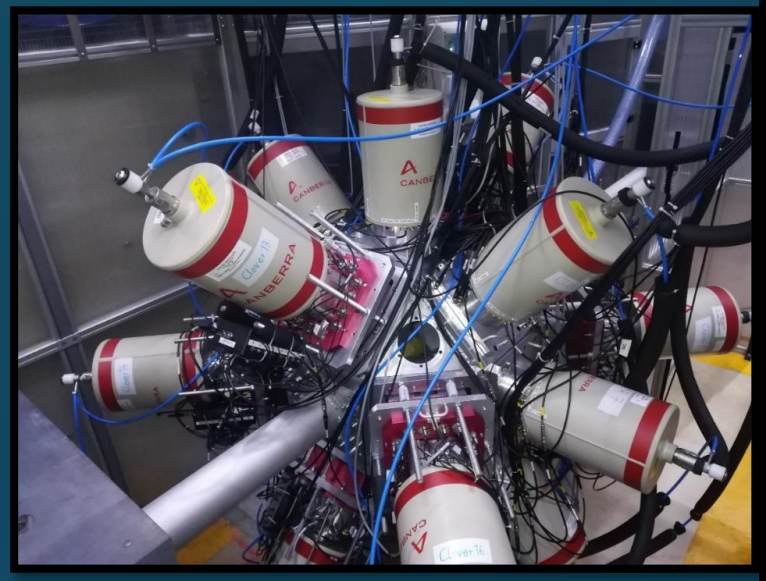
EXILL campaign EXogam@ILL (2012)

- 10 clover detectors
- 6 large coaxial detectors

- Neutrons induced fission of on ^{235}U and ^{241}Pu

Ł. W. Iskra *et al.*, p.64 Annual Report ILL (2017)
Ł. W. Iskra *et al.*, EPL 117, 12001 (2017)
Ł. W. Iskra *et al.*, Acta Phys. Pol. B 48, 581 (2017)
Ł. W. Iskra *et al.*, Phys. Scripta, 92, 10 (2017)
Ł. W. Iskra et al., EPN, 48 3, 14 (2017)

FIPPS FIssion Product Prompt *y*-ray Spectrometer



- 16 clover detectors

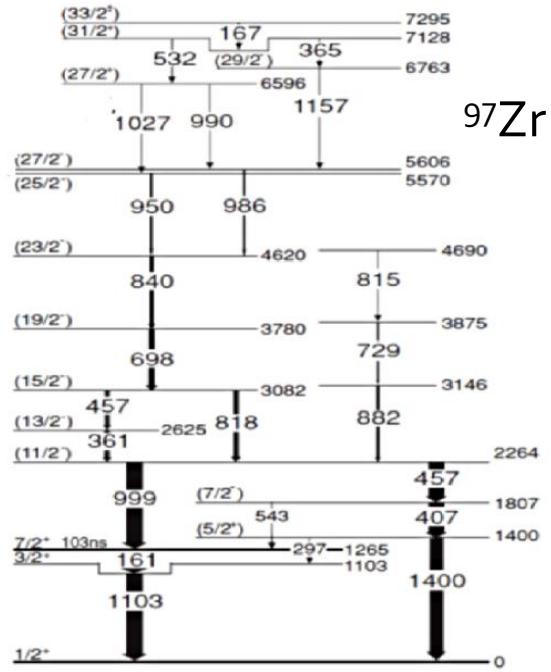
C. Michelagnoli *et al.*, EPJ **193**, 04009 (2018).

- Neutron induced fission of on ^{233}U and ^{235}U

- ~50 days of measurements with each target

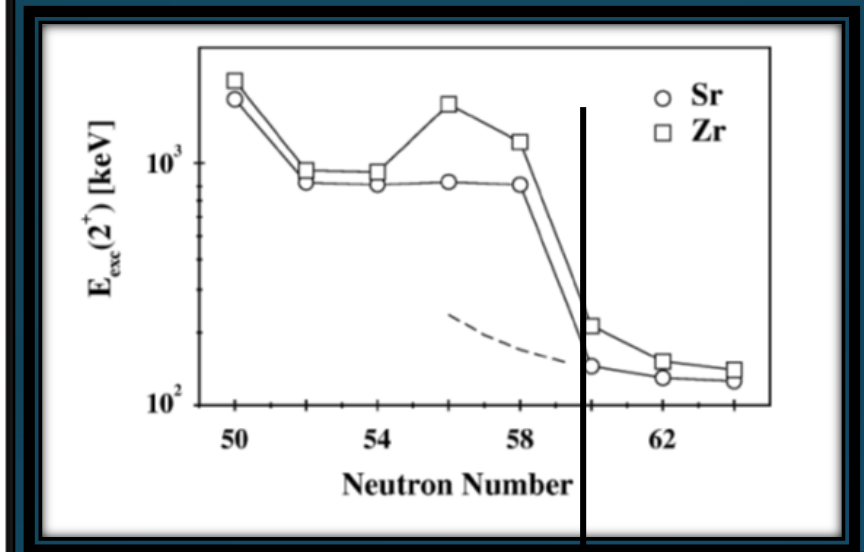
Searching for the onset of shape coexistence before $N = 60$

M. Matejska-Minda, B. Fornal et al., PRC 80, 017302(2009)



^{97}Zr

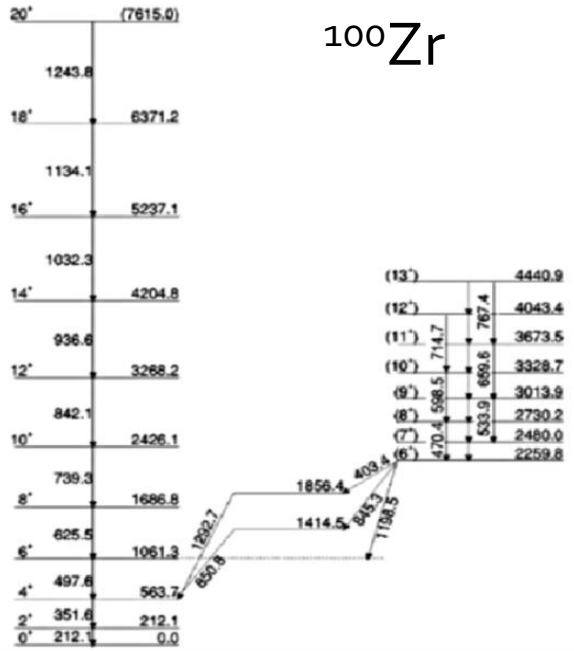
$Z = 40$



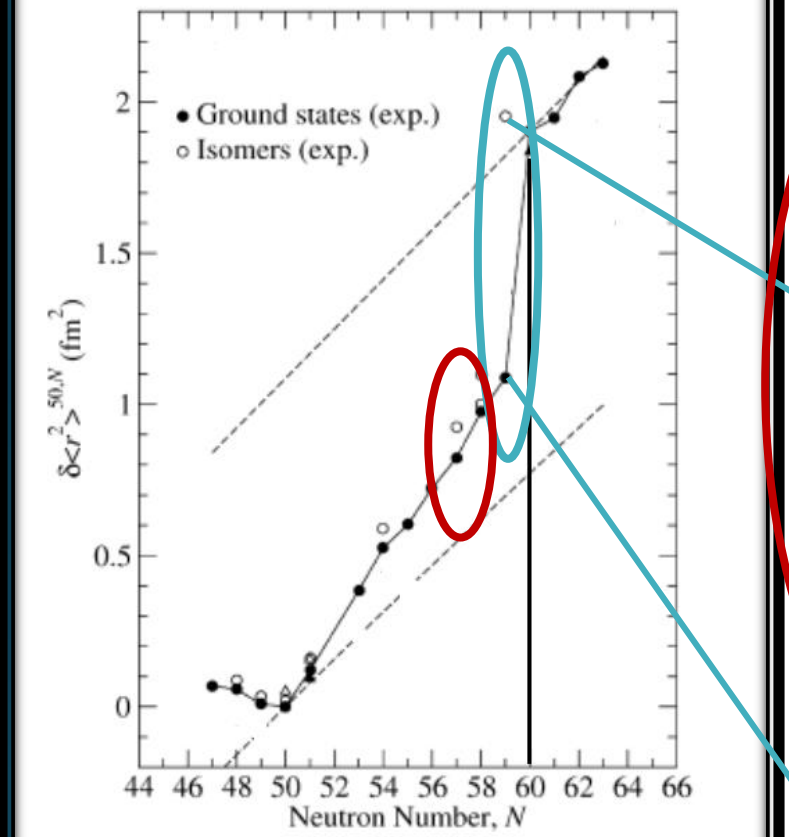
97Nb	98Nb	99Nb	100Nb	101Nb	102Nb	103Nb
96Zr	97Zr	98Zr	99Zr	100Zr	101Zr	102Zr
95Y	96Y	97Y	98Y	99Y	100Y	101Y
94Sr	95Sr	96Sr	97Sr	98Sr	99Sr	100Sr

$N = 60$

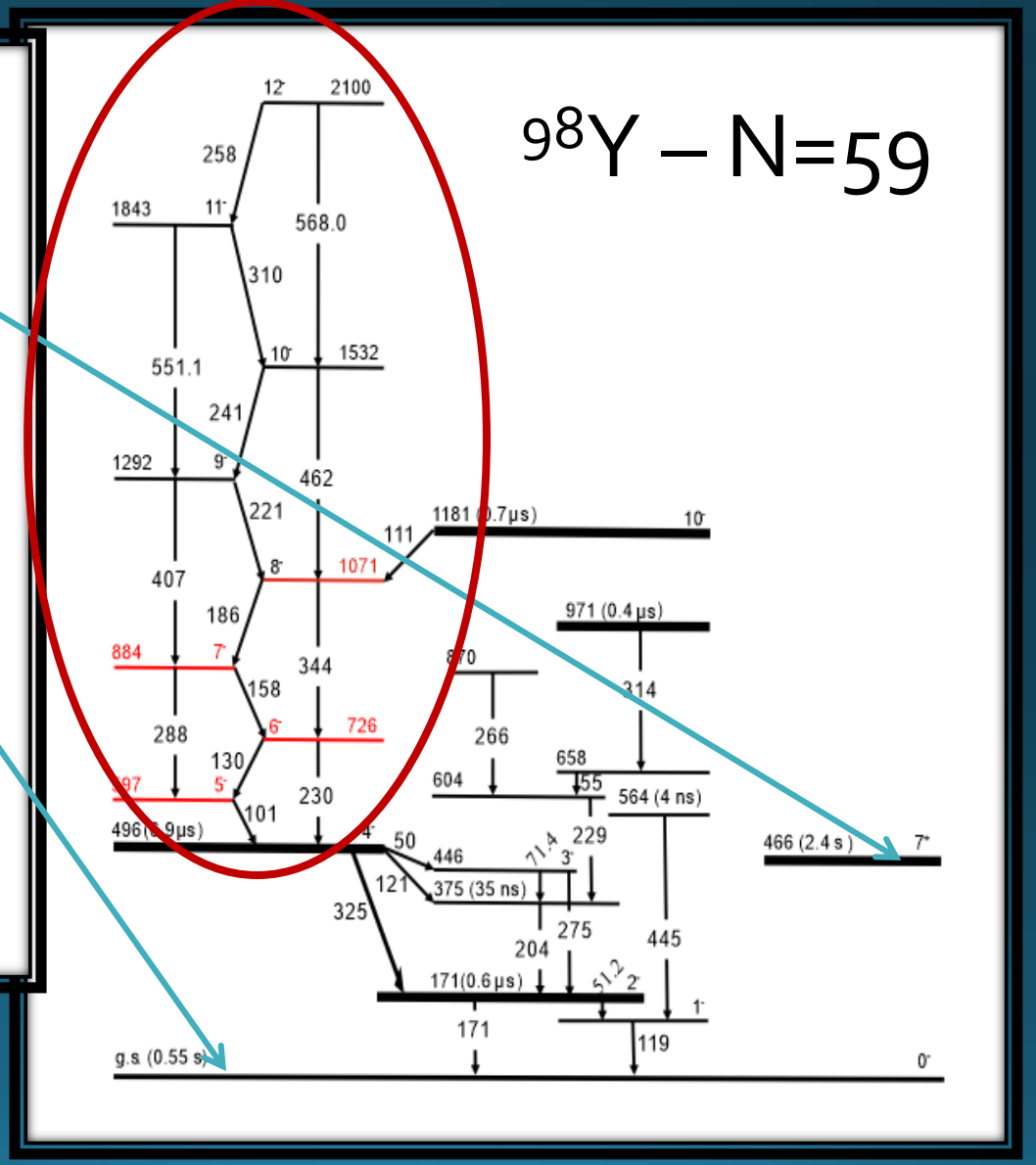
H. Hua et al., PRC 69, 014317 (2004)



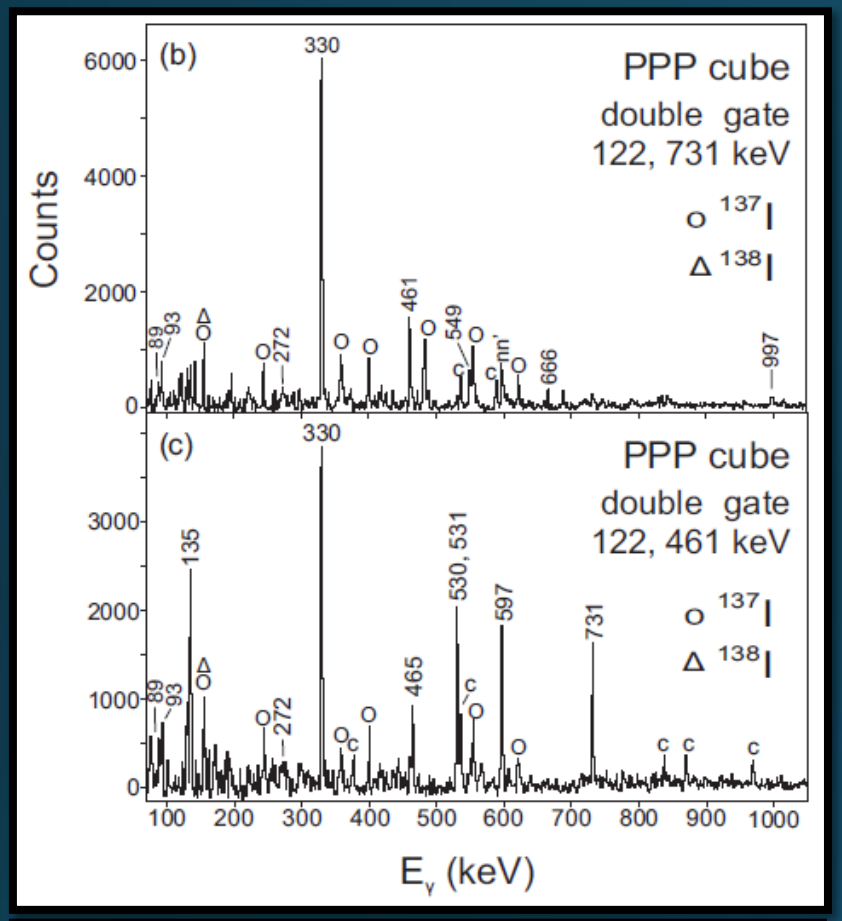
Searching for the onset of shape coexistence before $N = 60$

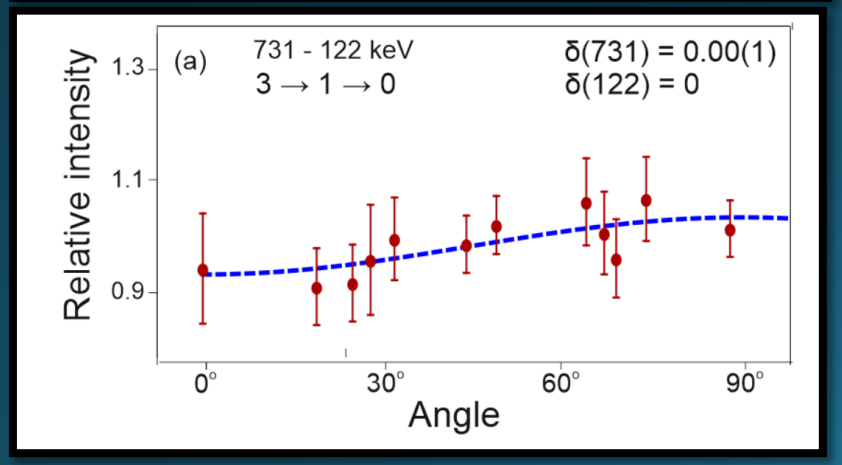


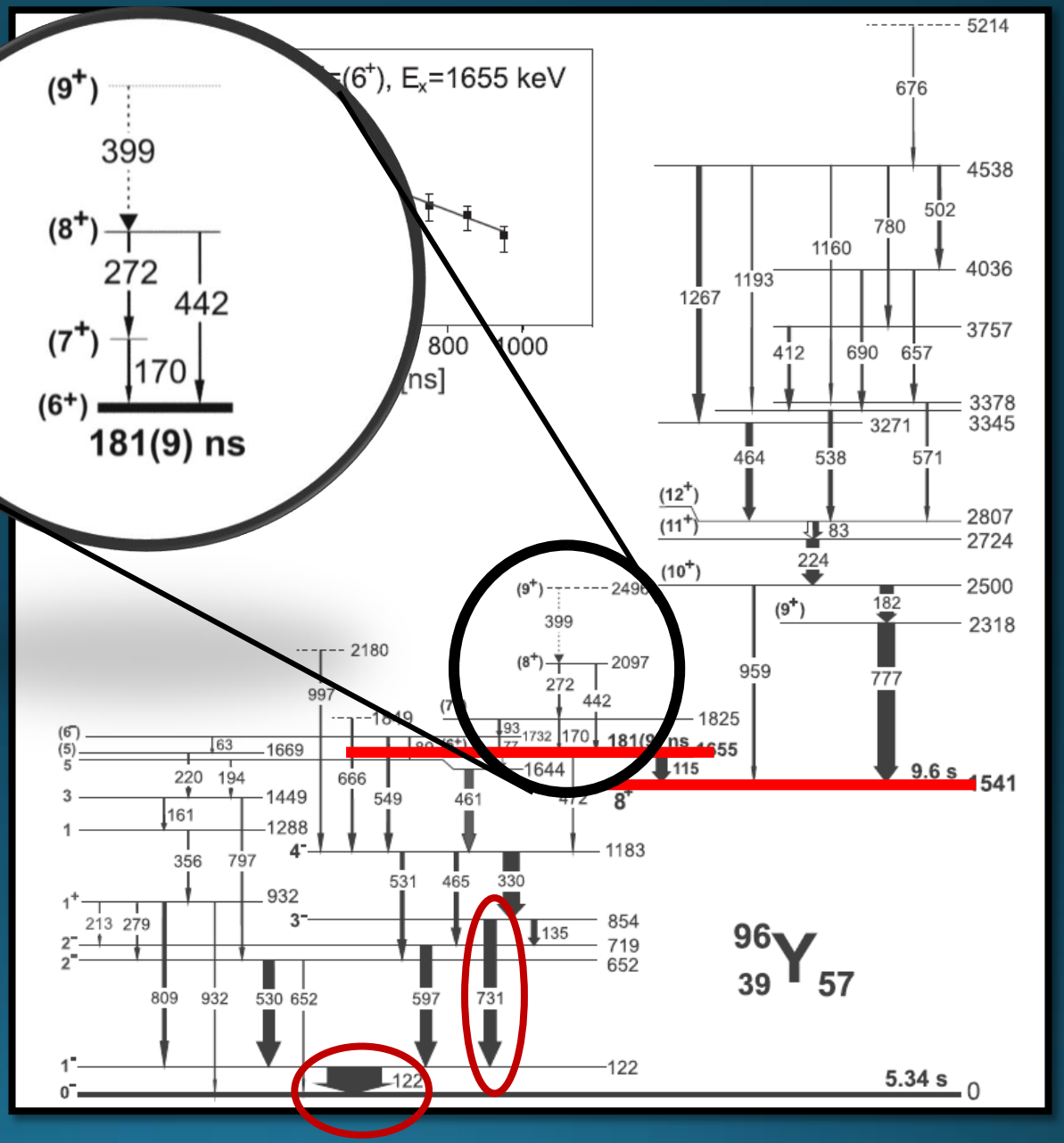
B. Cheal *et al.*, Phys Lett B **645**, 133-137 (2007).



W. Urban (Ł.W. Iskra) et al.., PRC **96**, 044333 (2017)



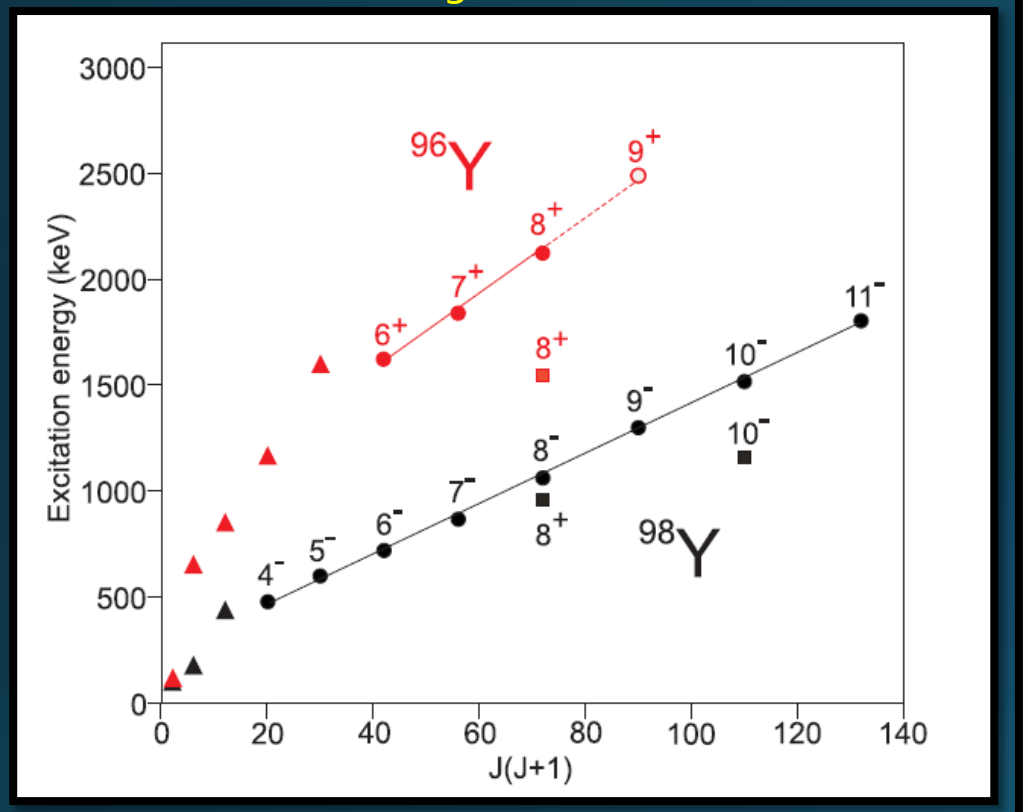


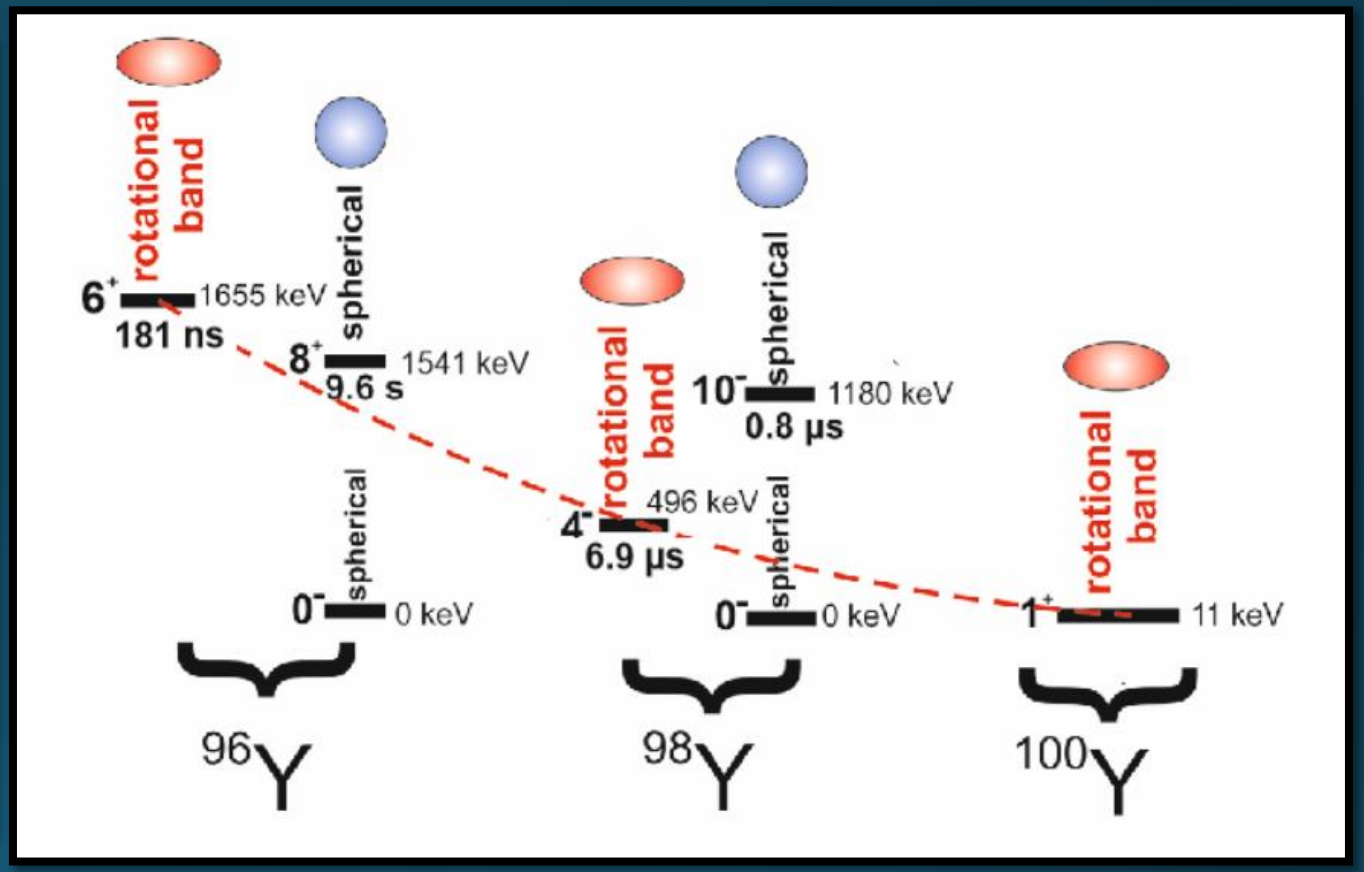


Ł. W. Iskra, S. Leoni, B. Fornal et al., PRC **102**, 054324 (2020)

Shape evolution in the Y isotopic chain

Hartree-Fock-Bogoliubov calculations

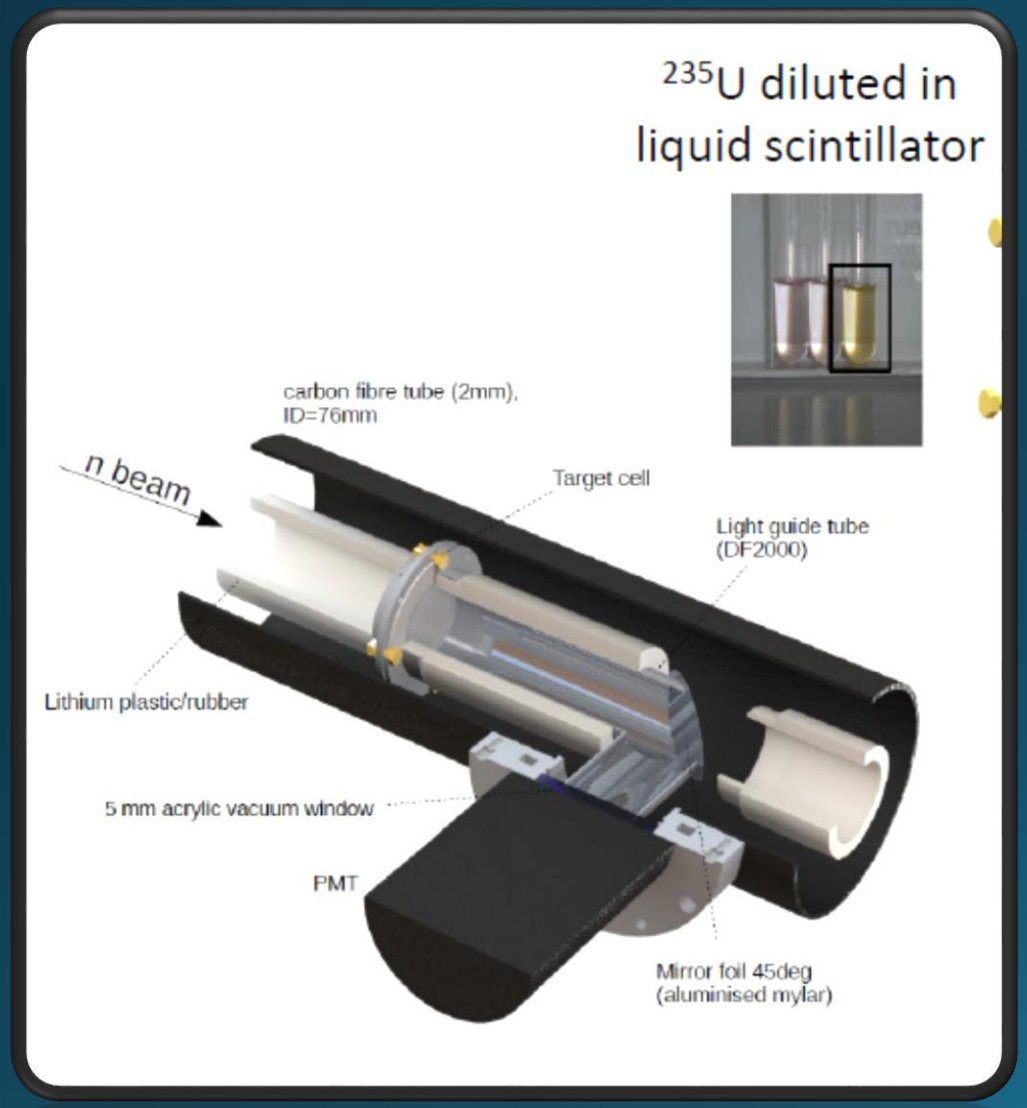


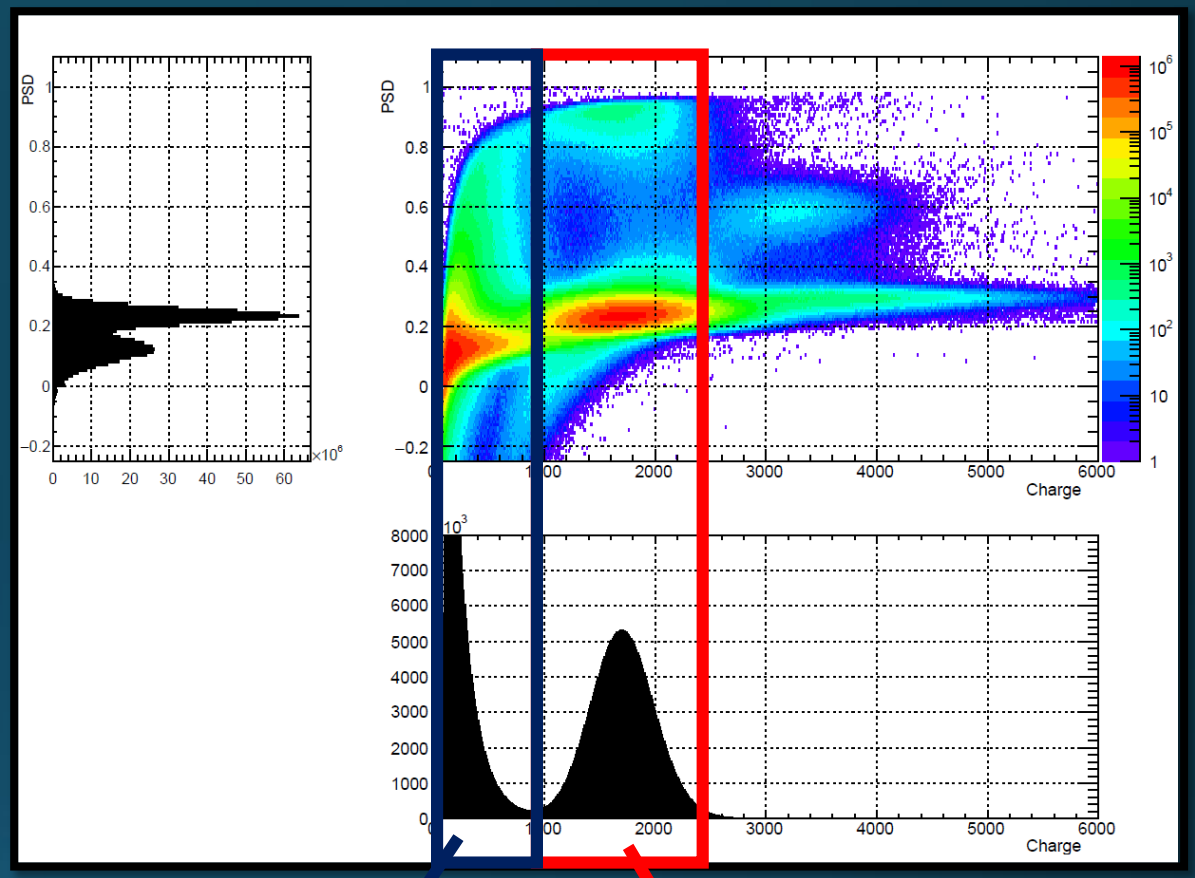


No sudden onset of deformation at N = 60 but graduall decrease in energy !?

First observation of a deformed structure in an *N* = 57 isotone

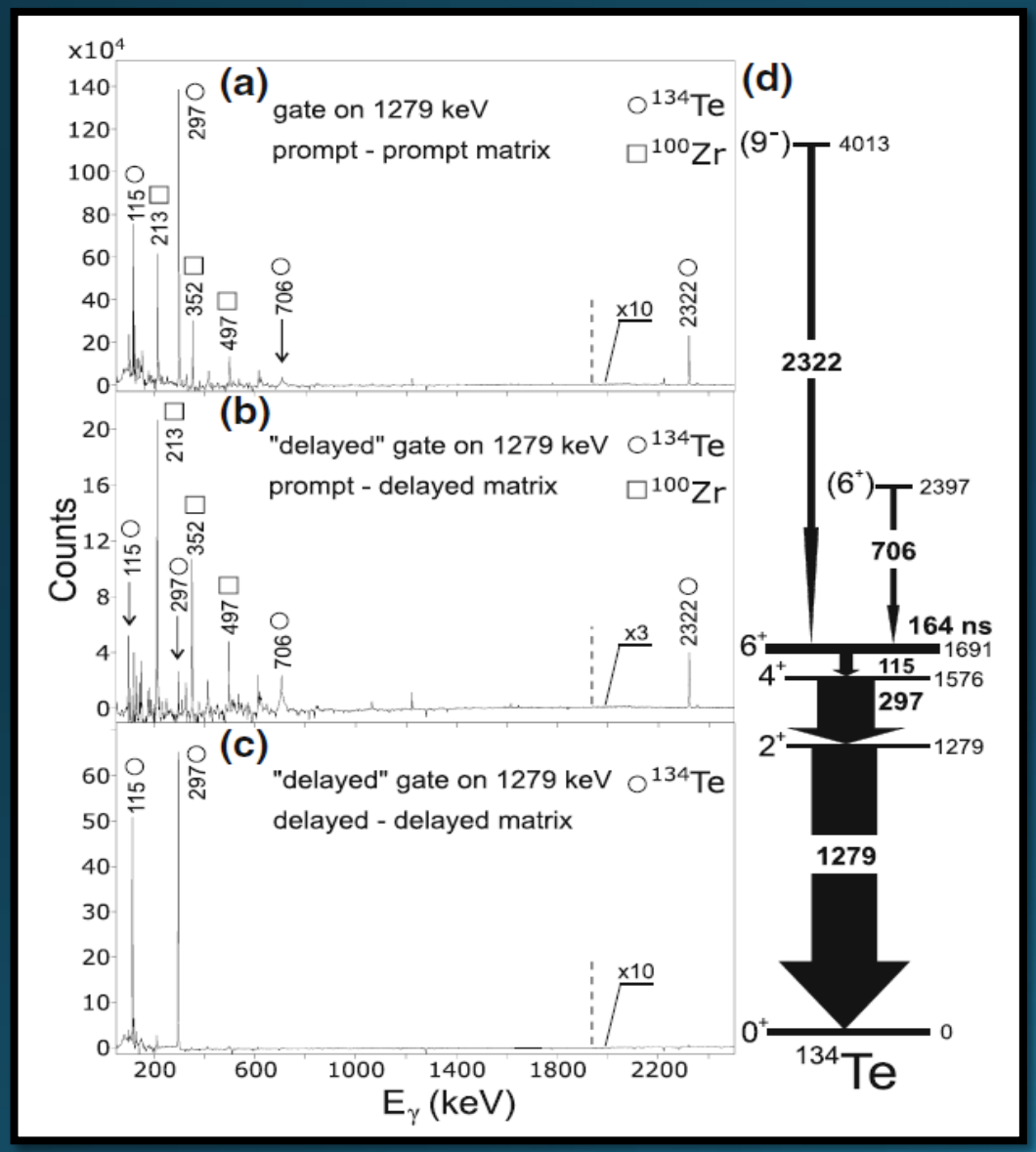
Active fission target





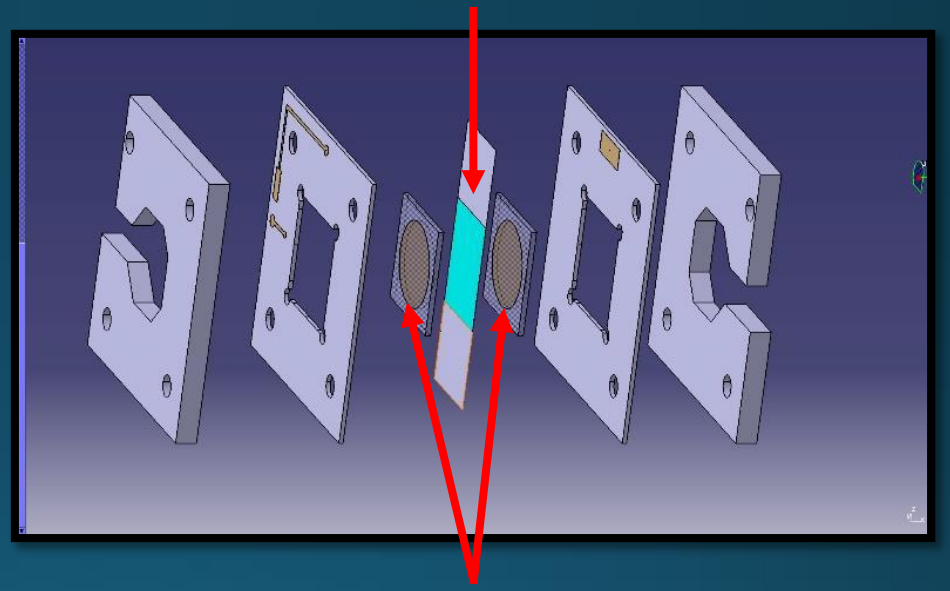
F. Kandzia (Ł. W . Iskra) *et al.*, Eur. Phys. J. A **56**, 207 (2020).

Active fission target



- $^{235}U(n,f)$
- $^{233}U(n,f)$
- $^{239,241}Pu$, $^{243,245,247}Cm$, ^{242}Am, ...

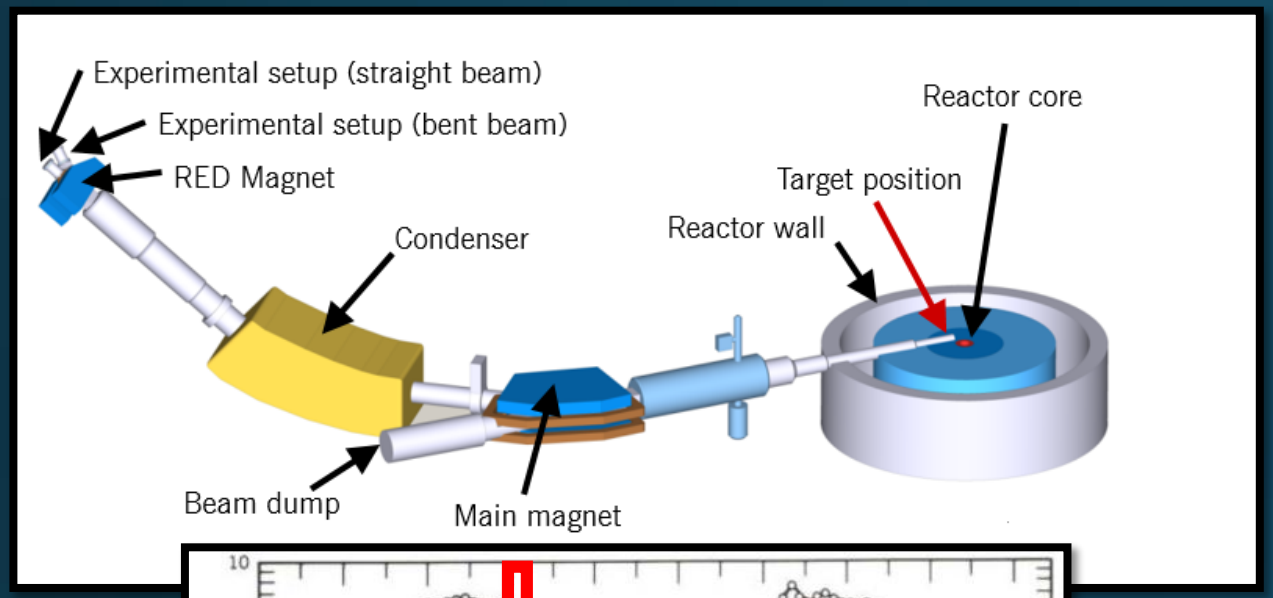
solid target

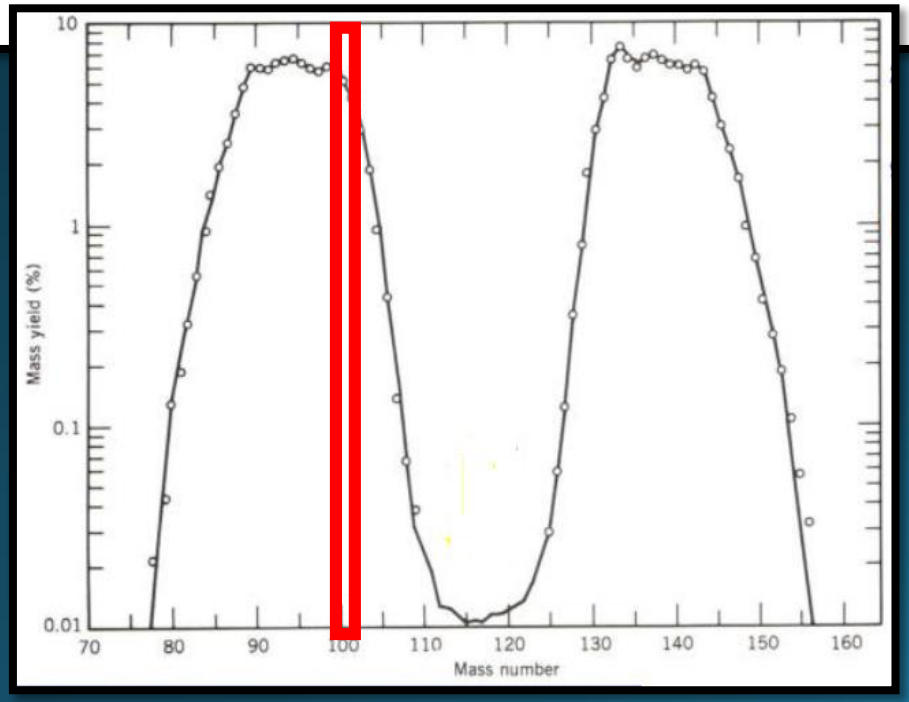


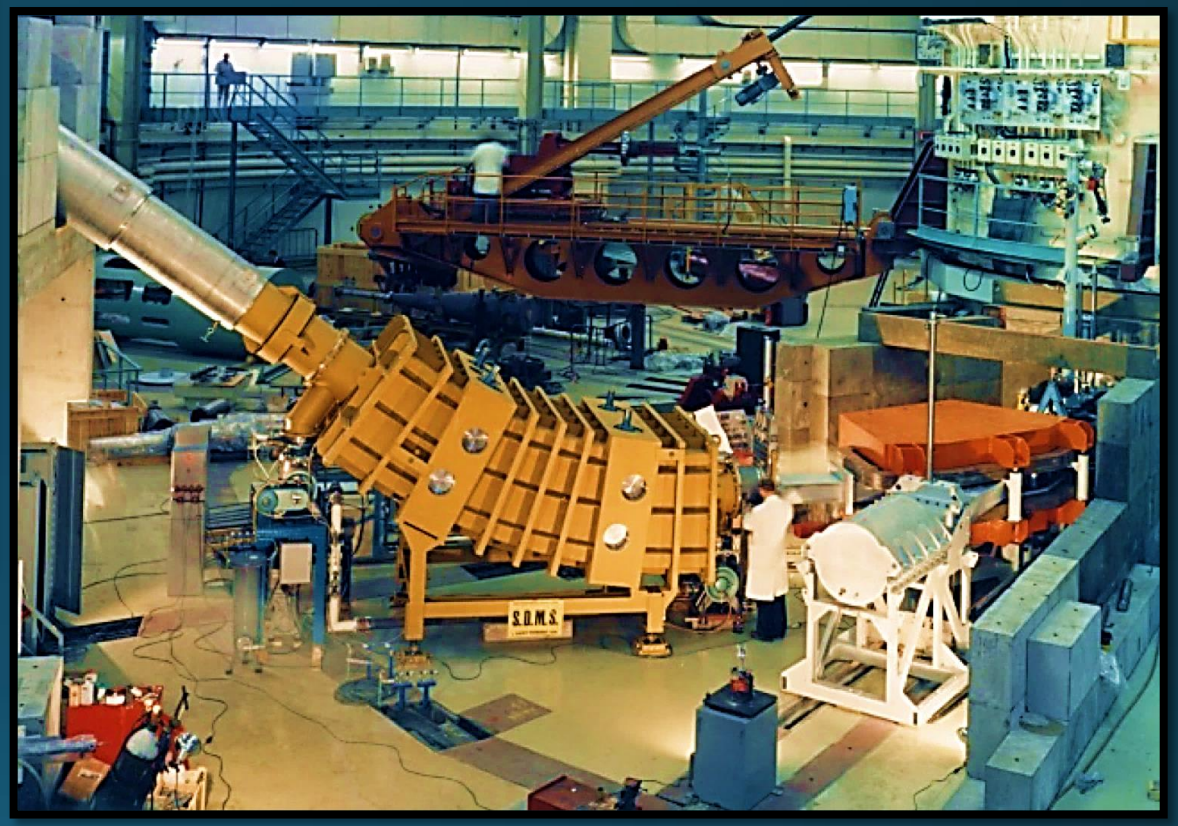
detectors

- ~~Silicon detectors (Si)~~
- Diamond detectors (CVD)
- Silicon carbide detectors (SiC)

LOHENGRIN fission fragment separator







Mass-separated fragments, ~10^5 /s, $t_{1/2}$ ~ µs

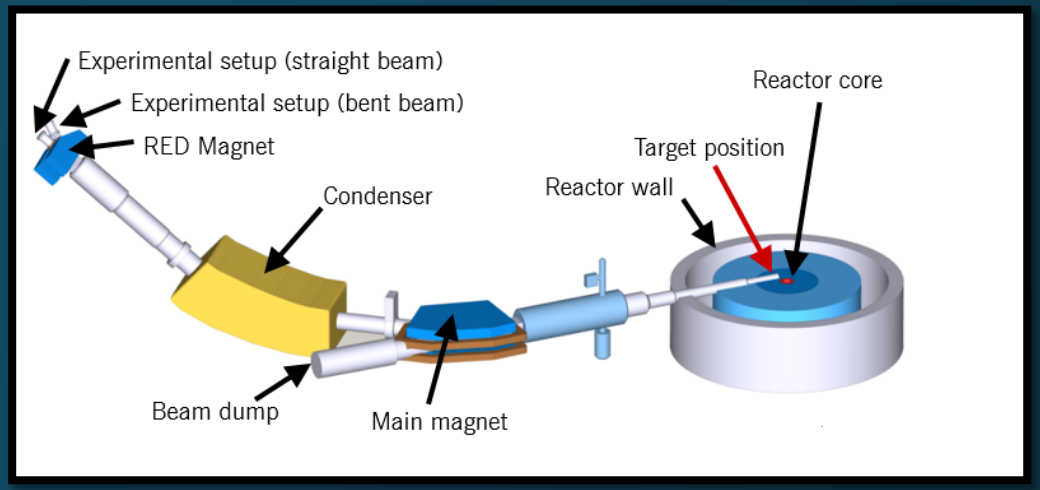
Test of diamond detectors with LOHENGRIN

2 × 2 mm²

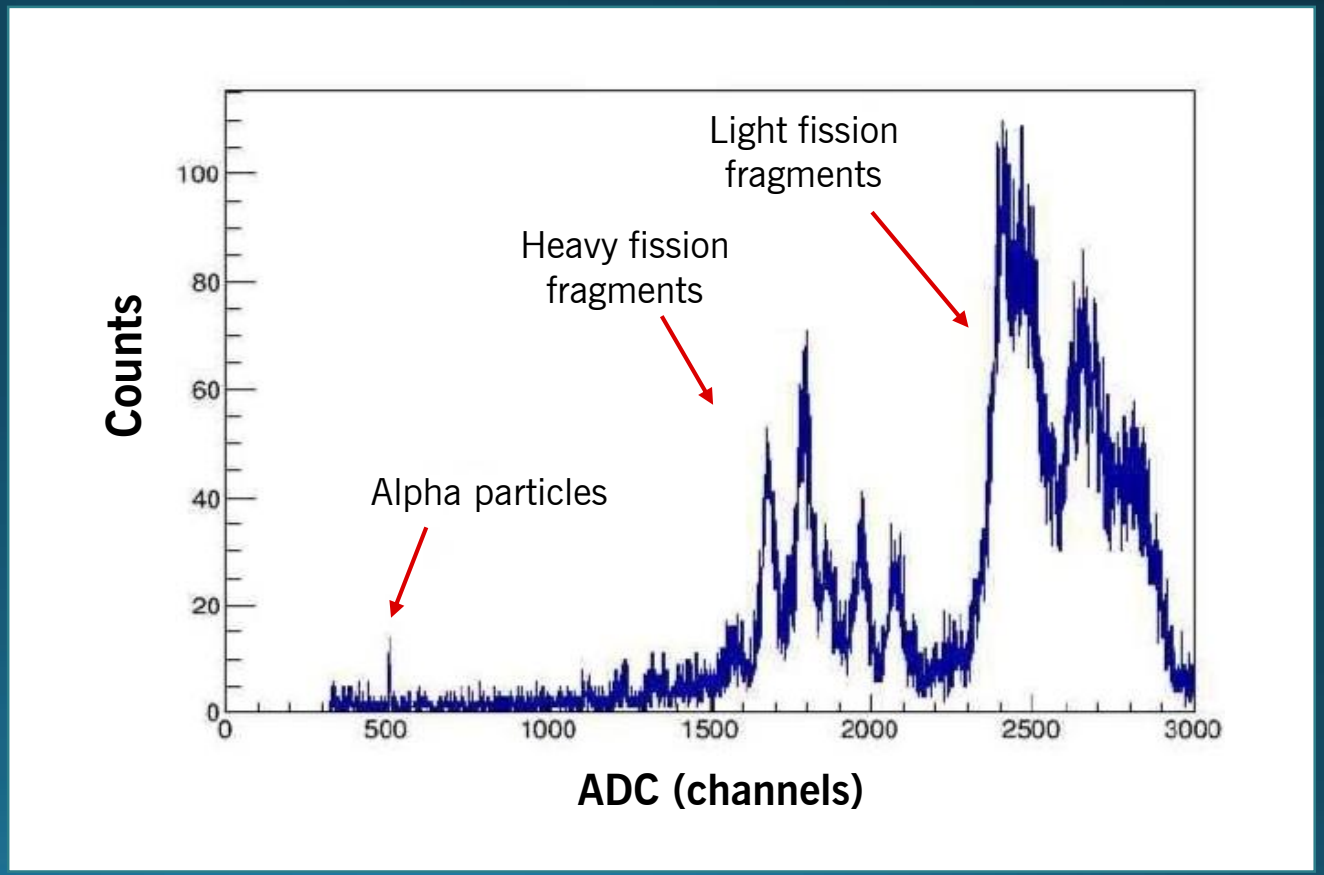
IFJ PAN

10 × 10 mm²

LPSC Grenoble

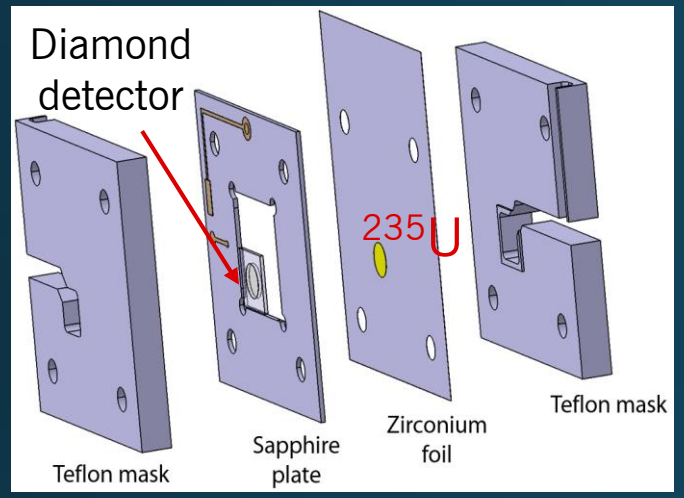


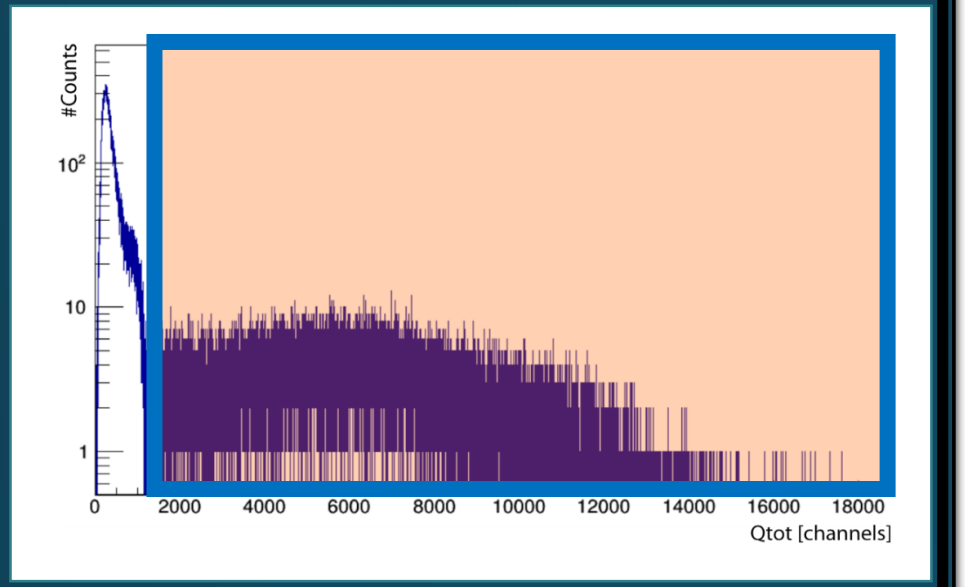
Preamplifiers , electronic suport
and data acquisition system:
INFN Milano - C. Boiano and S. Brambilla

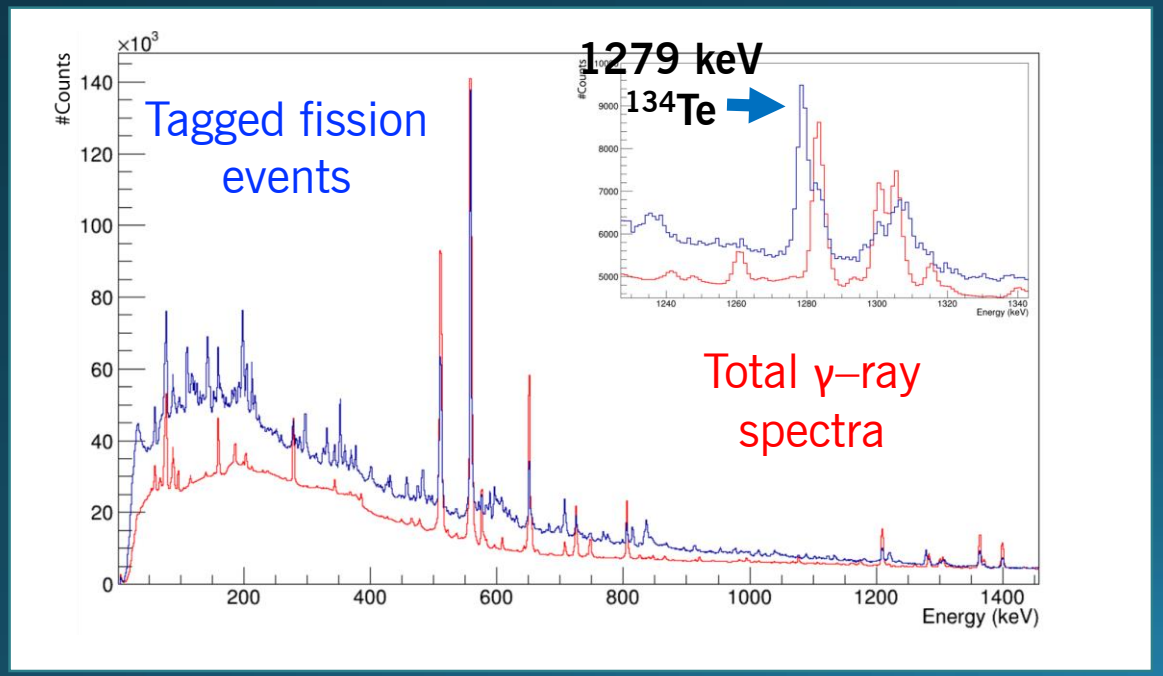


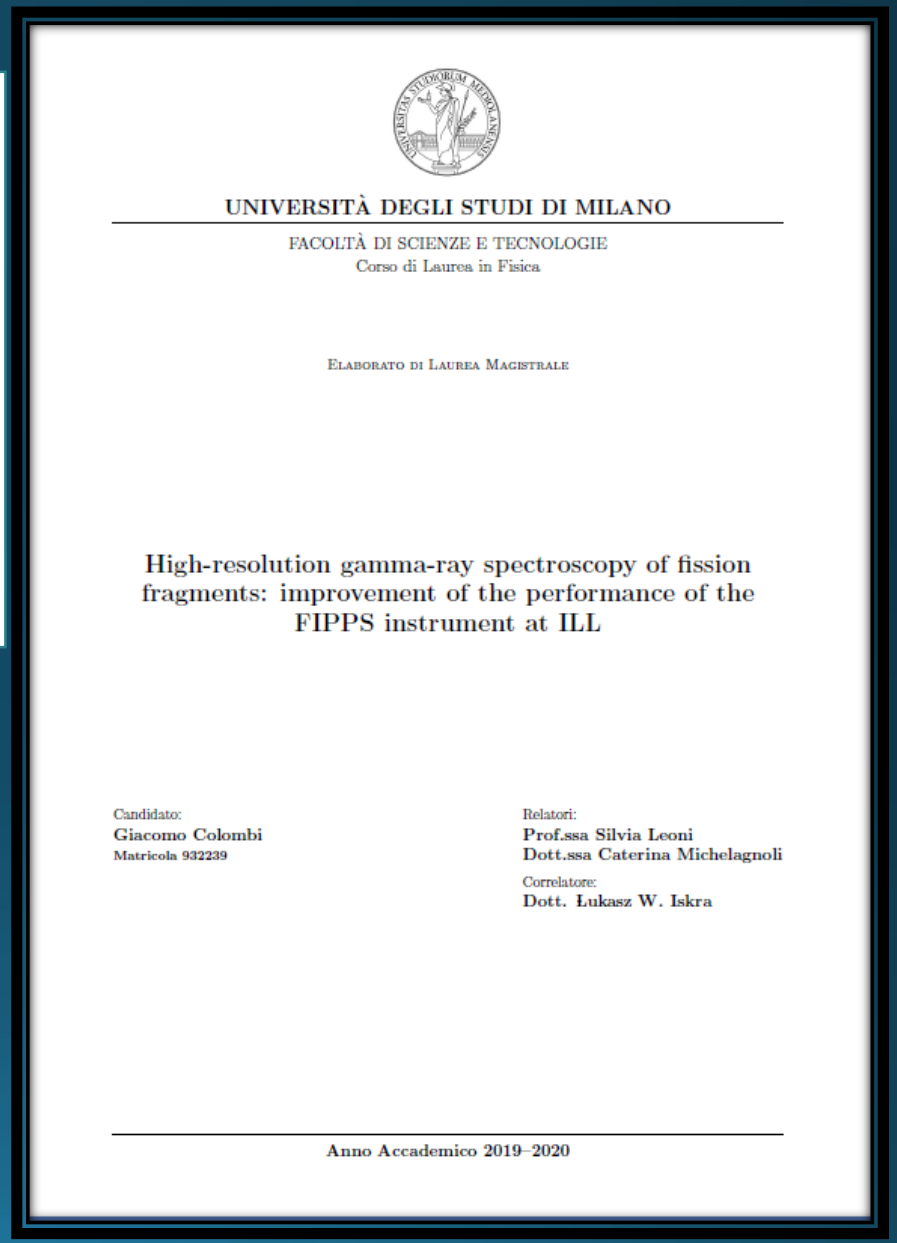
Test of diamond detectors with FIPPS

Figures from the thesis









UNIVERSITÀ DEGLI STUDI DI MILANO

FACOLTÀ DI SCIENZE E TECNOLOGIE
Corso di Laurea in Fisica

ELABORATO DI LAUREA MAGISTRALE

High-resolution gamma-ray spectroscopy of fission fragments: improvement of the performance of the FIPPS instrument at ILL

Candidato:
Giacomo Colombi
Matricola 932239

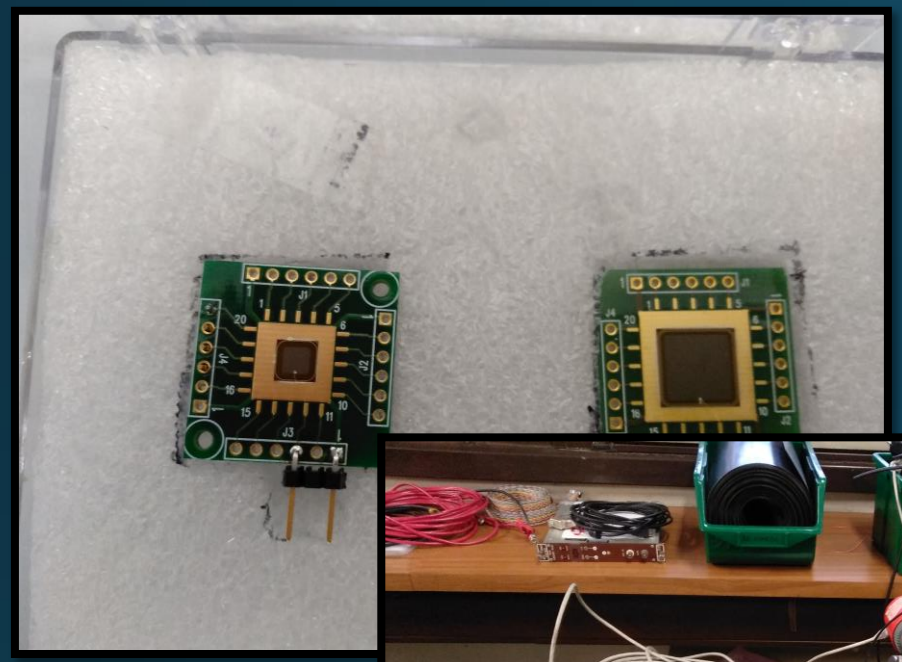
Relatori:
Prof.ssa Silvia Leoni
Dott.ssa Caterina Michelagnoli

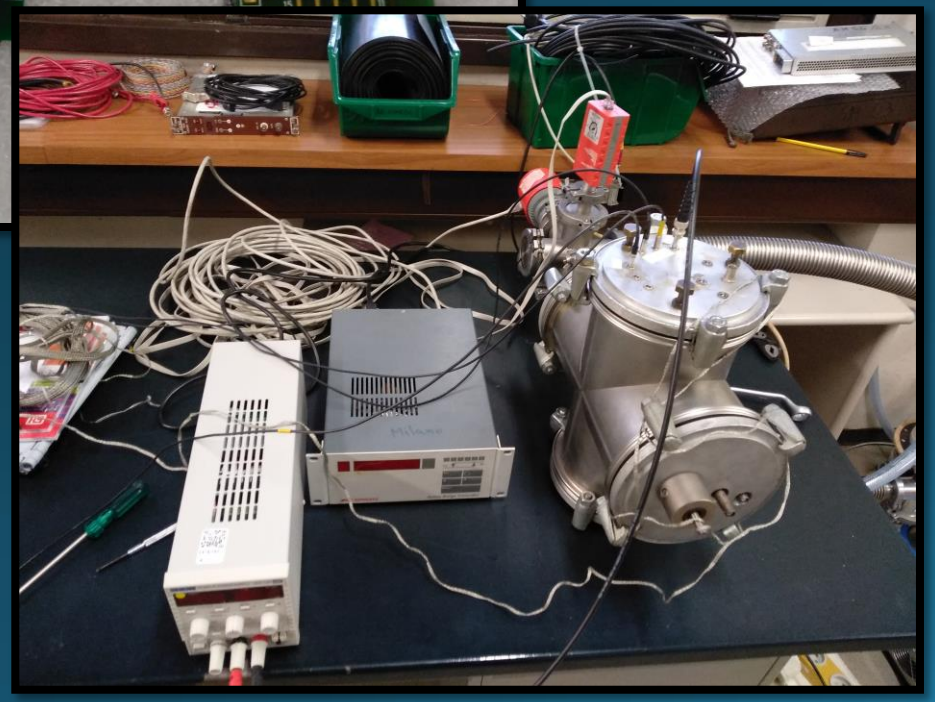
Correlatore:
Dott. Łukasz W. Iskra

Anno Accademico 2019–2020

Test of SiC detectors

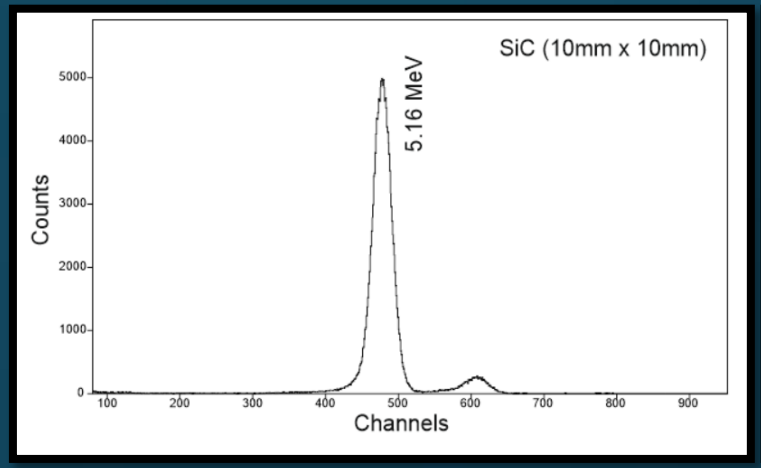
Two SiC detectors received from INFN-Catania



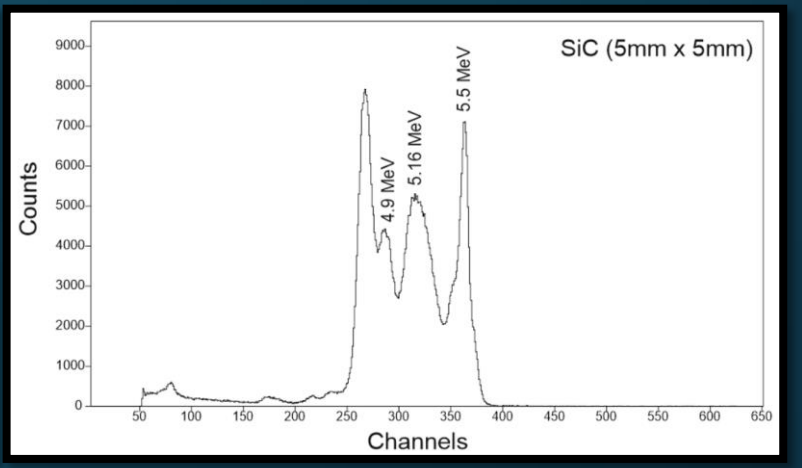


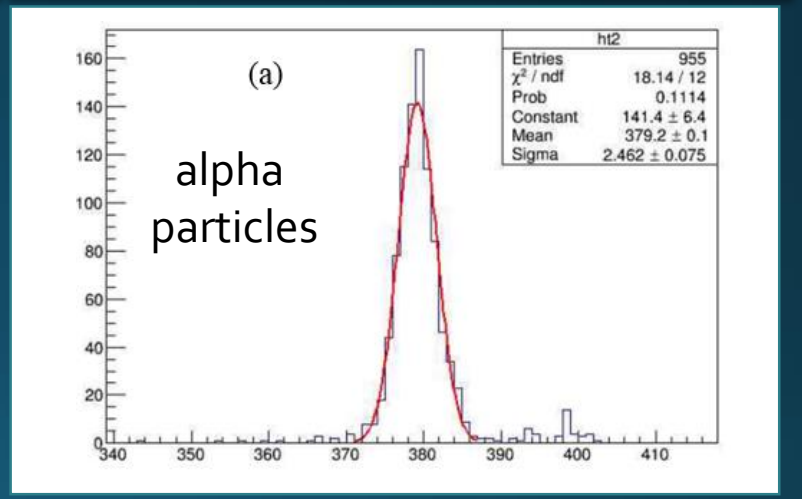
AIX-Marseille University

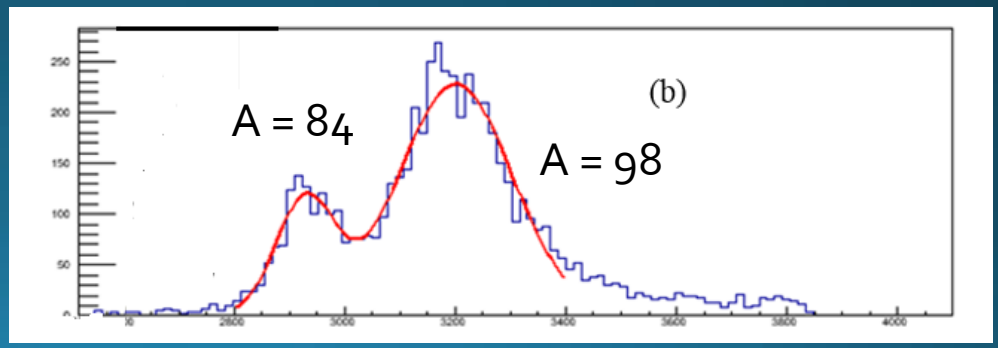
^{239}Pu alpha source



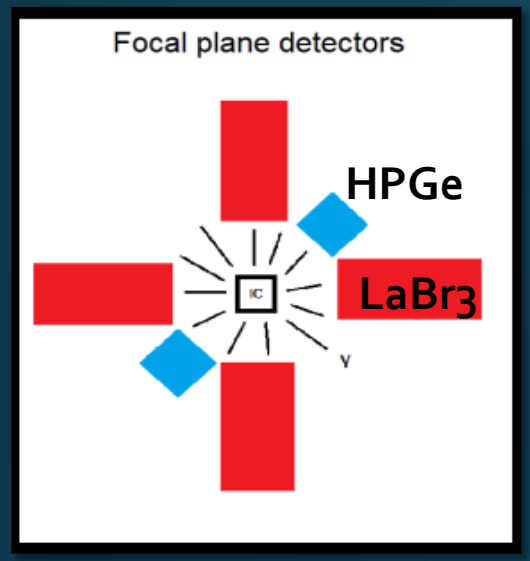
^{233}U + ^{239}Pu + ^{238}Pu alpha sources

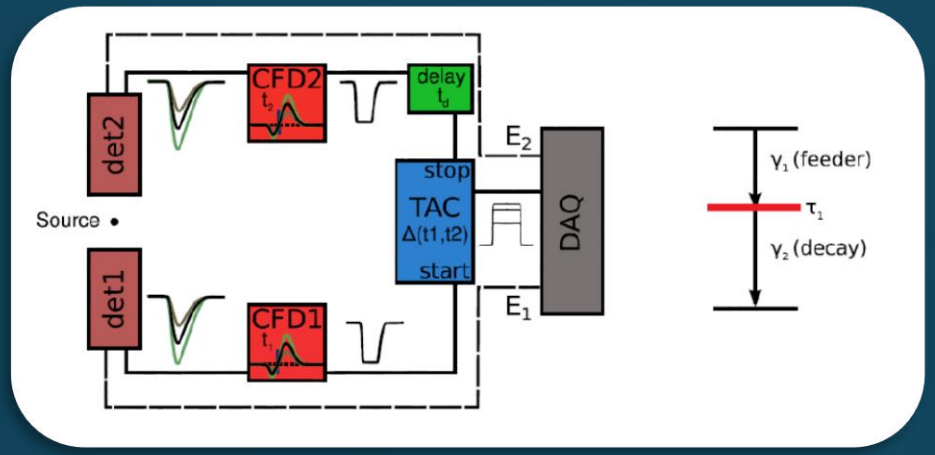




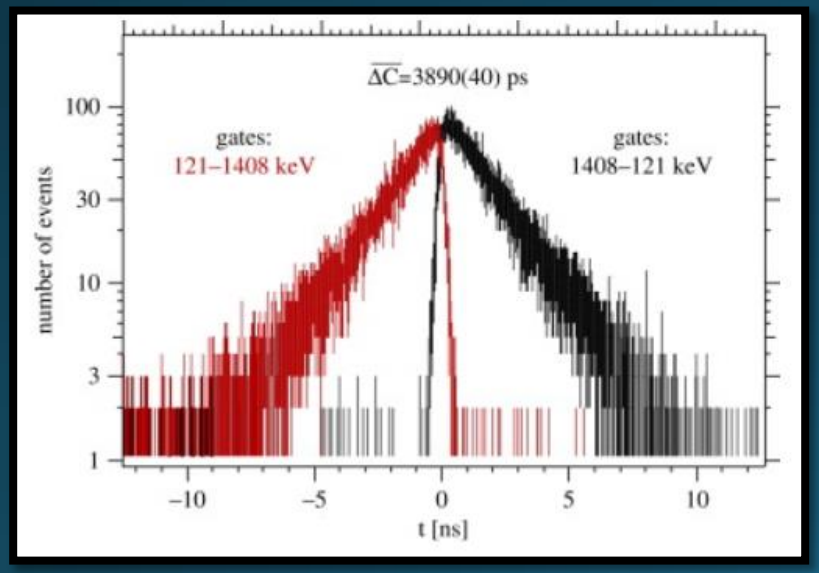


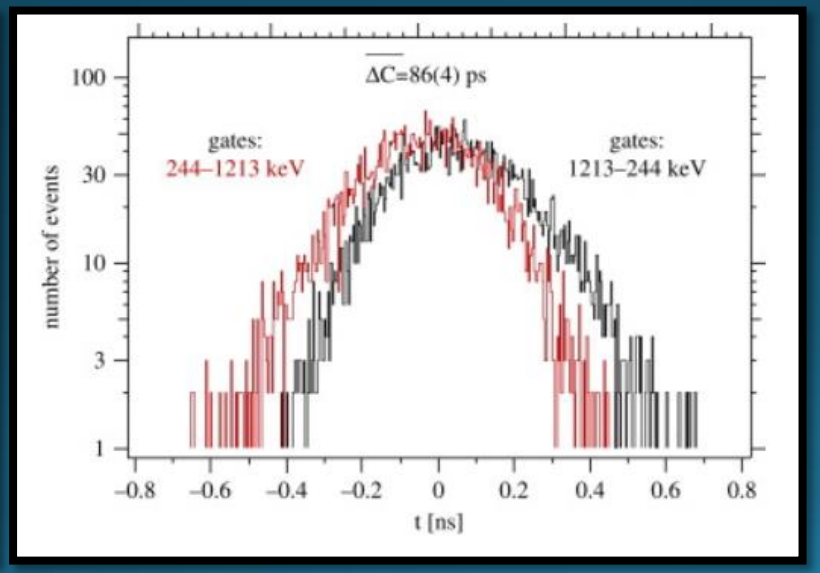
Lifetimes measurement with LOHENGRIN

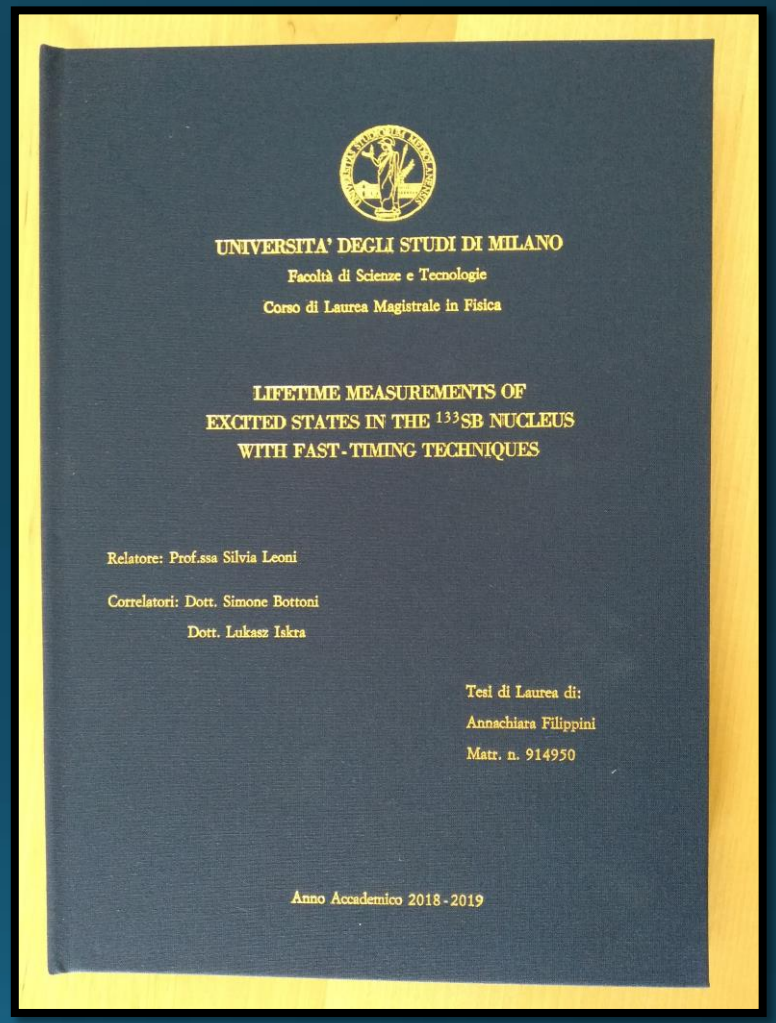




J.-M. Régis et al., NIM A 955, 163258 (2020)






UNIVERSITA' DEGLI STUDI DI MILANO

Facoltà di Scienze e Tecnologie

Corso di Laurea Magistrale in Fisica

LIFETIME MEASUREMENTS OF EXCITED STATES IN THE ^{133}SB NUCLEUS WITH FAST-TIMING TECHNIQUES

Relatore: Prof.ssa Silvia Leoni

Correlatori: Dott. Simone Bottoni

Dott. Lukasz Iskra

Tesi di Laurea di:

Annachiara Filippini

Matr. n. 914950

Anno Accademico 2018-2019

Lifetimes measurements with LOHENGRIN

- ^{96}Y – 22 days of measurement
- ^{95}Y – 10 days of measurement
- ^{94}Y - 6 days of measurement
- ^{93}Y – 3 days of measurement

ILL RESEARCH PROPOSAL 26/08/2020

Title: **Study of the deformation of the 96Rb isotope via fast timing measurements**

3-01-688

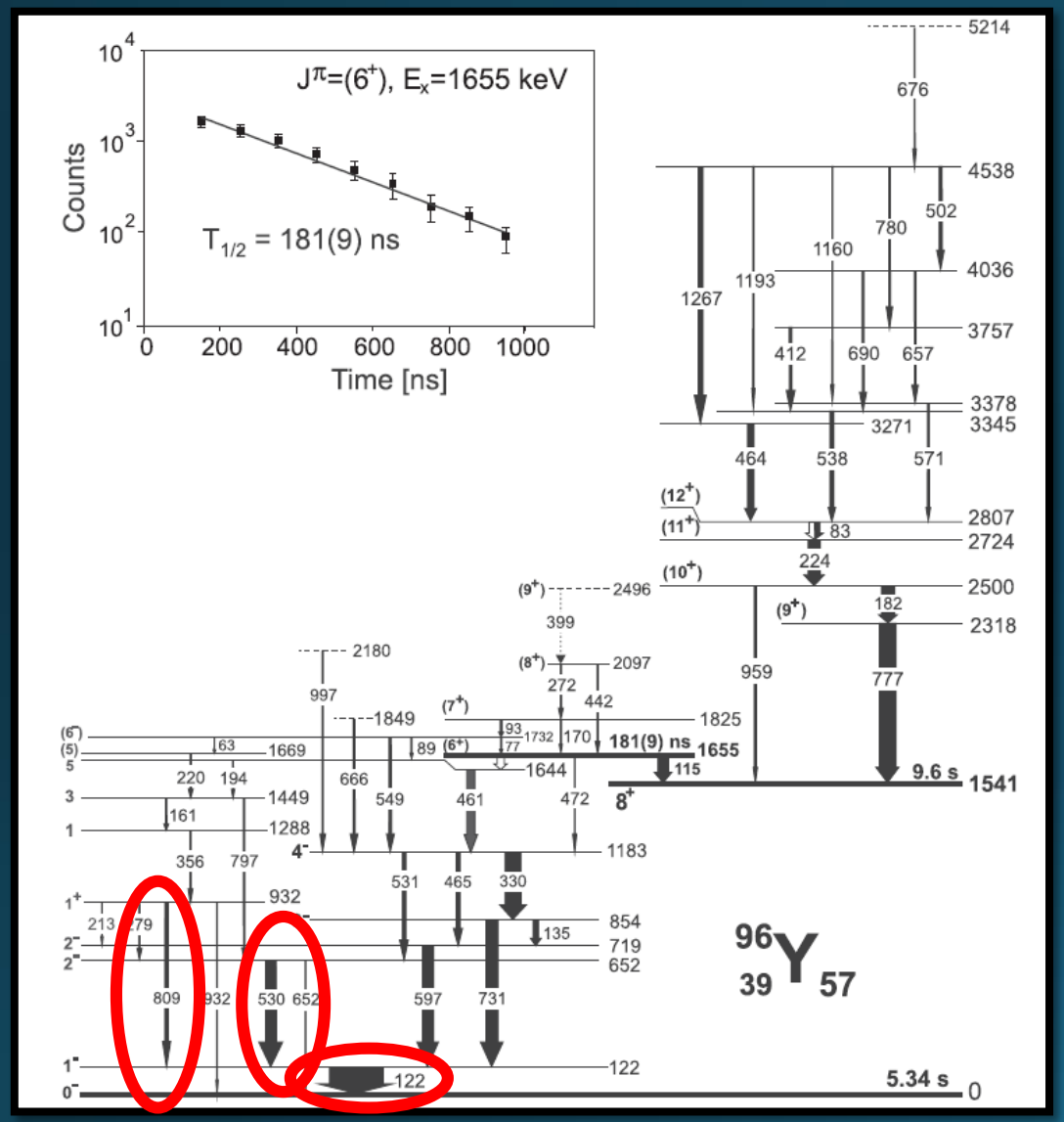
Proposer (to whom correspondence will be addressed)

Name and first name	Address	Phone	Email
Lukasz ISKRA	**INFN, MILANO** VIA CELORIA, 16 20133 MILANO ITALY	696900713	lukasz.iskra@ifj.edu.pl

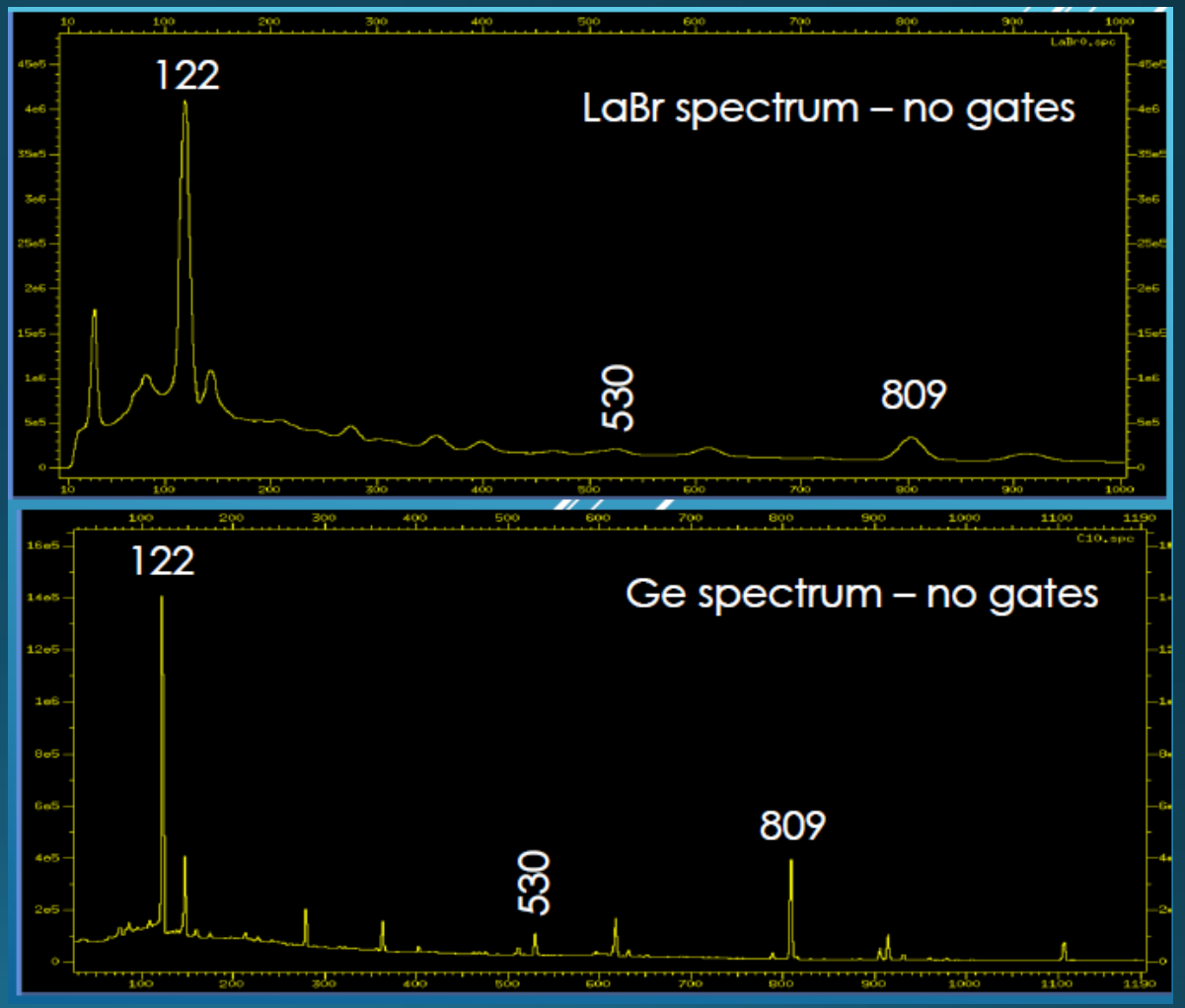
New neutron user: **No** New ILL user: **No**

Local contact contacted: **Yes**

Lifetimes measurement with LOHENGRIN

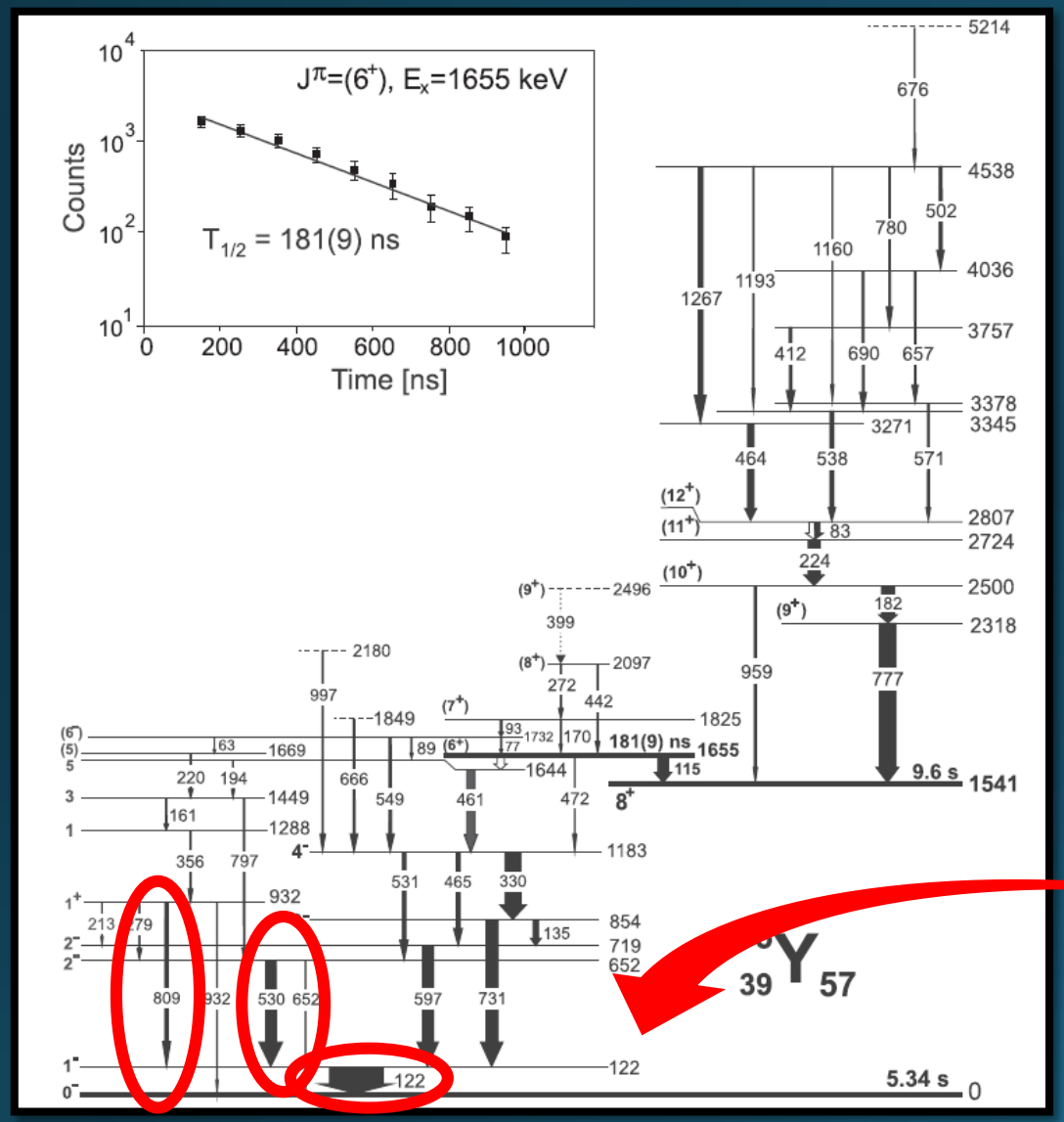


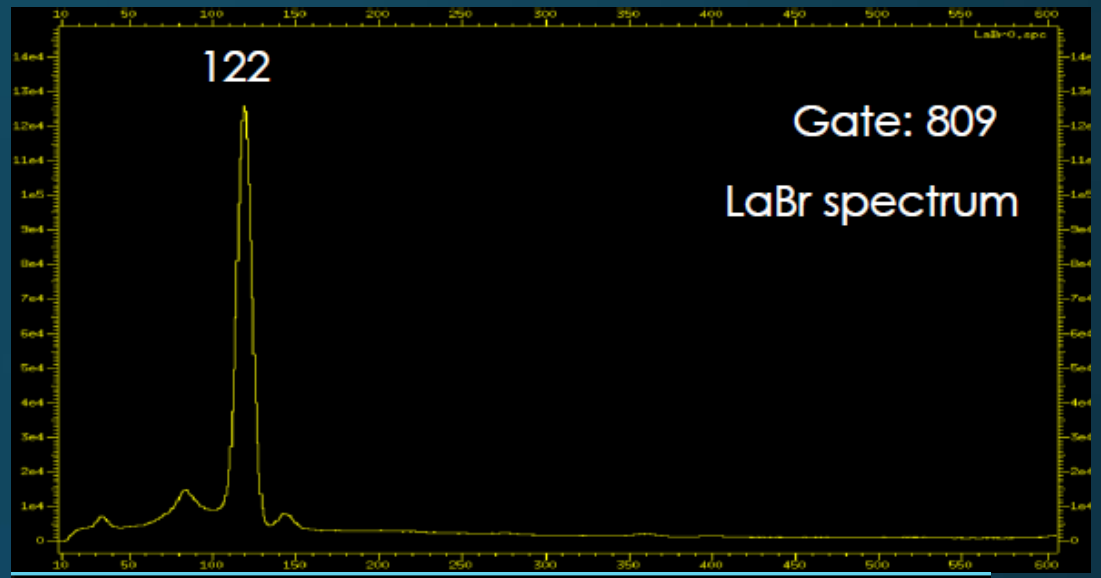
A = 96

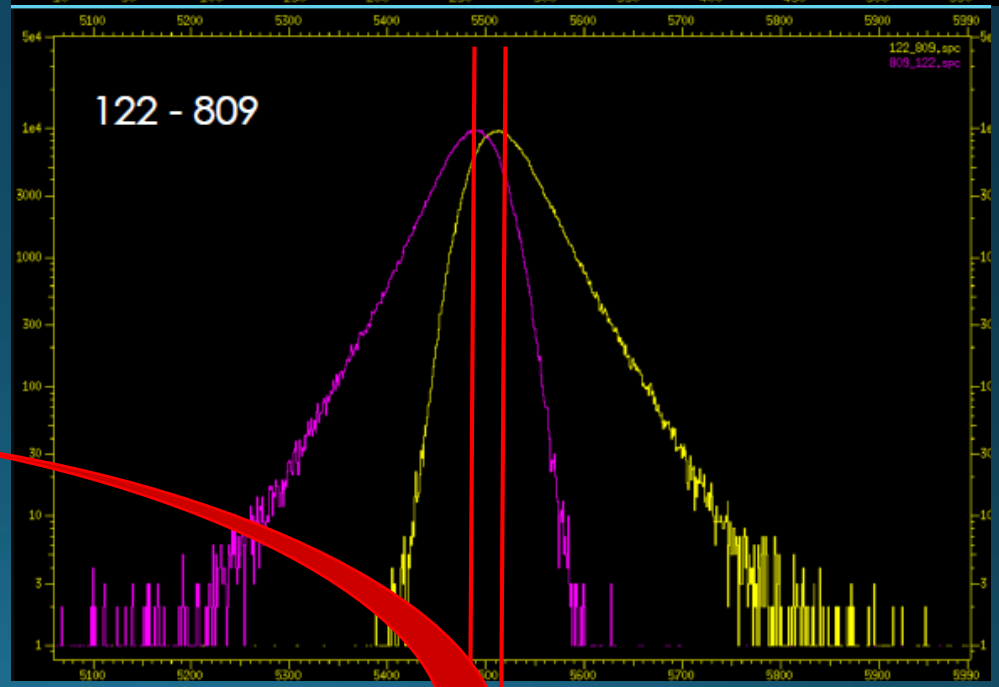


Ł. W. Iskra, S. Leoni, B. Fornal et al., PRC **102**, 054324 (2020)

Lifetimes measurement with LOHENGRIN



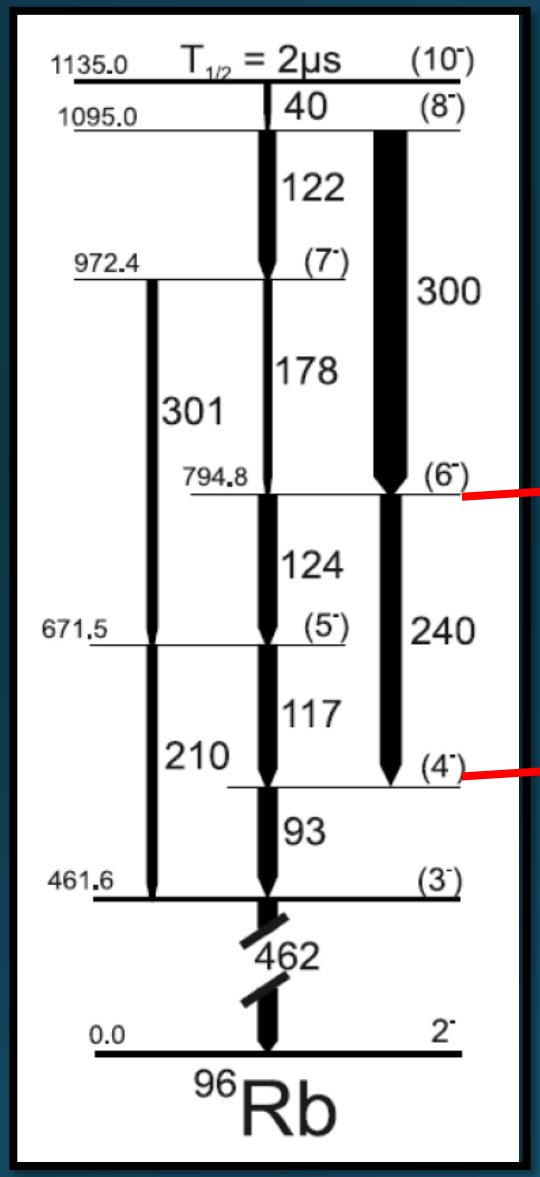


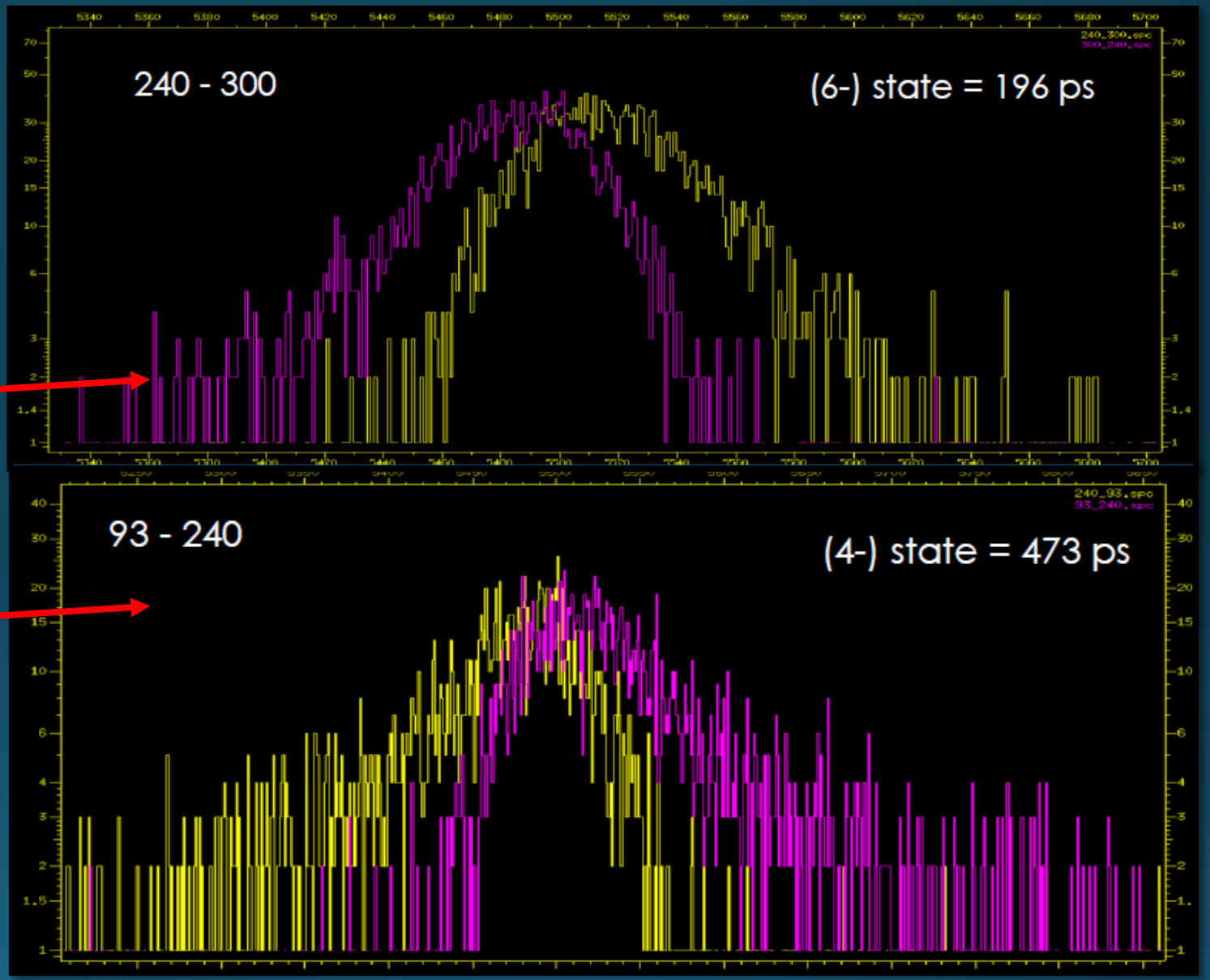


T1/2 = 191(8) ps

Ł. W. Iskra, S. Leoni, B. Fornal et al., PRC **102**, 054324 (2020)

Lifetimes measurement with LOHENGRIN





J. Dudouet et al., PRL 118, 162501 (2017).

Summary

Scientific line :

- Gamma spectroscopy of neutron-rich isotopes produced in neutron-induced fission process
  - Studies of nuclei in N-E of double magic ^{78}Ni; searching for neutron radioactivity
    - fast-nautron-induced fission of ^{232}Th target (*IJCLab* Orsay with v-ball array)
  - Searching for shape coexistence in nuclei around Z = 40, N = 60; studies of onset and evolution of the deformed structures in Y isotopes
    - thermal-neutron-induced fission of ^{233}U and ^{235}U targets (ILL Grenoble with FIPPS array)
  - Studies of the deformed structures in Y and Rb isotopes via lifetimes measurement
    - thermal-neutron-induced fission ^{235}U target (ILL Grenoble with LOHENGRIN mass spectrometer)
- Development of new instruments for fission experiments
  - Active target based on liquid scintillator – efficient fission tag
  - Active targets based on diamond or SiC detectors
  - Development of Gas Filled Magent for FIPPS array (near future)

Collaboration group

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Università degli Studi and INFN sez. Milano

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IJCLab, Orsay, France

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ILL, Grenoble, France

Thank you
for your attention