# Fusion and breakup fusion of $^{6}$Li with $^{194}$Pt at energies around Coulomb barrier

Catalin Borcea

Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering

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# Outline

- Motivation
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  - DAQ
- Data treatment
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# Motivation

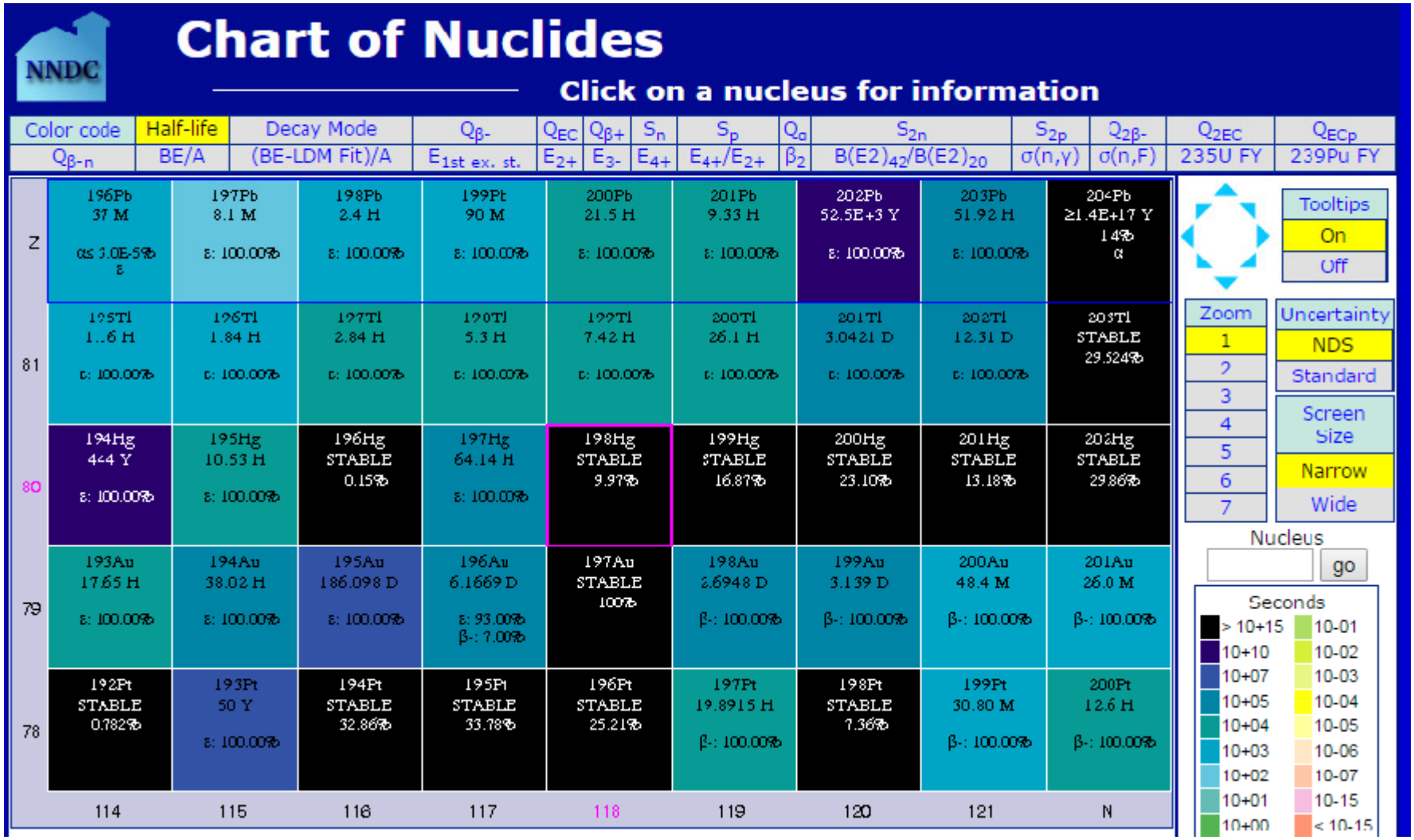


Chart of Nuclides
NNDC
Click on a nucleus for information
Color code
Half-life
Decay Mode
Qβ-
QEC
Qβ+
Sn
Sp
Qα
S2n
S2p
Q2β-
Q2EC
QECp
Qβ-n
BE/A
(BE-LDM Fit)/A
E1st ex. st.
E2+
E3-
E4+
E4+/E2+
β2
B(E2)42/B(E2)20
σ(n,γ)
σ(n,F)
235U FY
239Pu FY
Z
81
80
79
78
114
115
116
117
118
119
120
121
N
Tooltips
On
Off
Zoom
1
2
3
4
5
6
7
Uncertainty
NDS
Standard
Screen Size
Narrow
Wide
Nucleus
go
Seconds
> 10+15
10+10
10+07
10+05
10+04
10+03
10+02
10+01
10+00
10-01
10-02
10-03
10-04
10-05
10-06
10-07
10-15
< 10-15

# Experimental details

**Activation method:**

Beam: $^{6}Li$ @ 23, 24.5, 26, 28, 30, 32 and 34 MeV by the 9MV Bucharest TANDEM Accelerator

Irradiation procedure

- Monitoring: Faraday Coup+ guard ring (300V)
- Current integration (registered by a TNT card) – precise reconstruction of the number of nuclei produced as a function of :
  - Current variation (history of the irradiation)
  - Time elapsed between the irradiation time and the beginning of the measurement

Target: $^{194}Pt$ (96.45 % purity) + Al backing (3.7 μm)

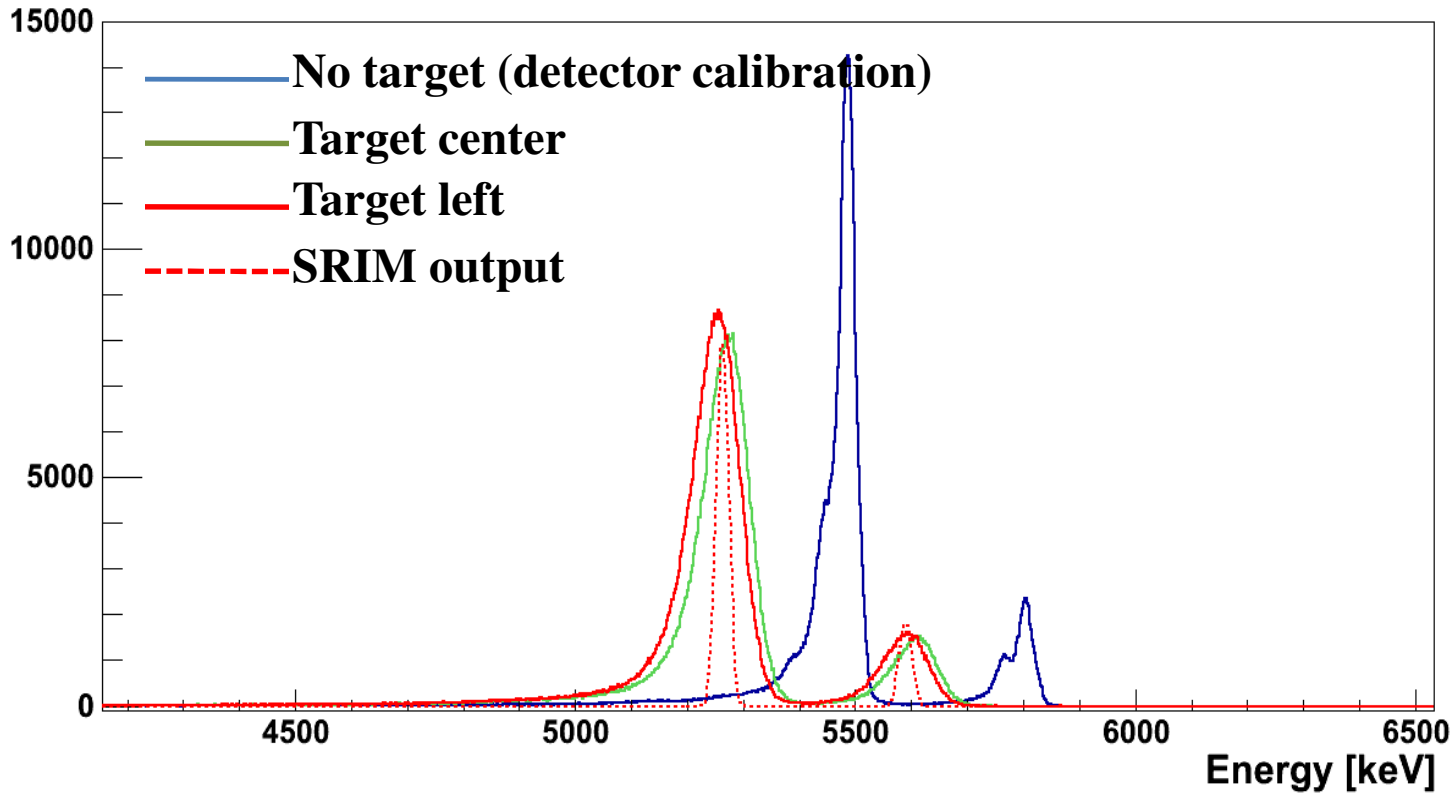
Detection setup:

- 2 HPGe (100%) placed in front of each other
- Lead Shield (minimum 10 cm)
- Two geometries : 10 & 1 cm (distance from the target position)
- Summing effect & dead time corrections

# Target thickness determination

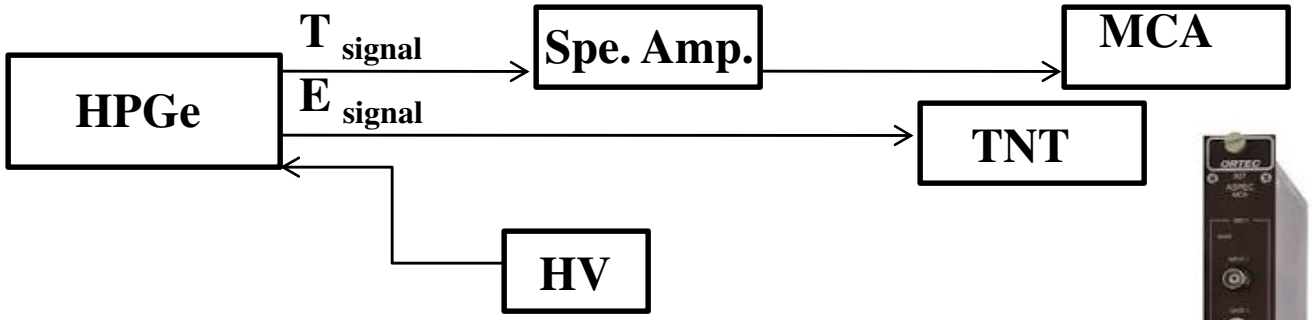
- α scattering method
- Comparison with SRIM simulations

$^{241}$Am radioactive source



# DAQ

## Two parallel acquisition systems



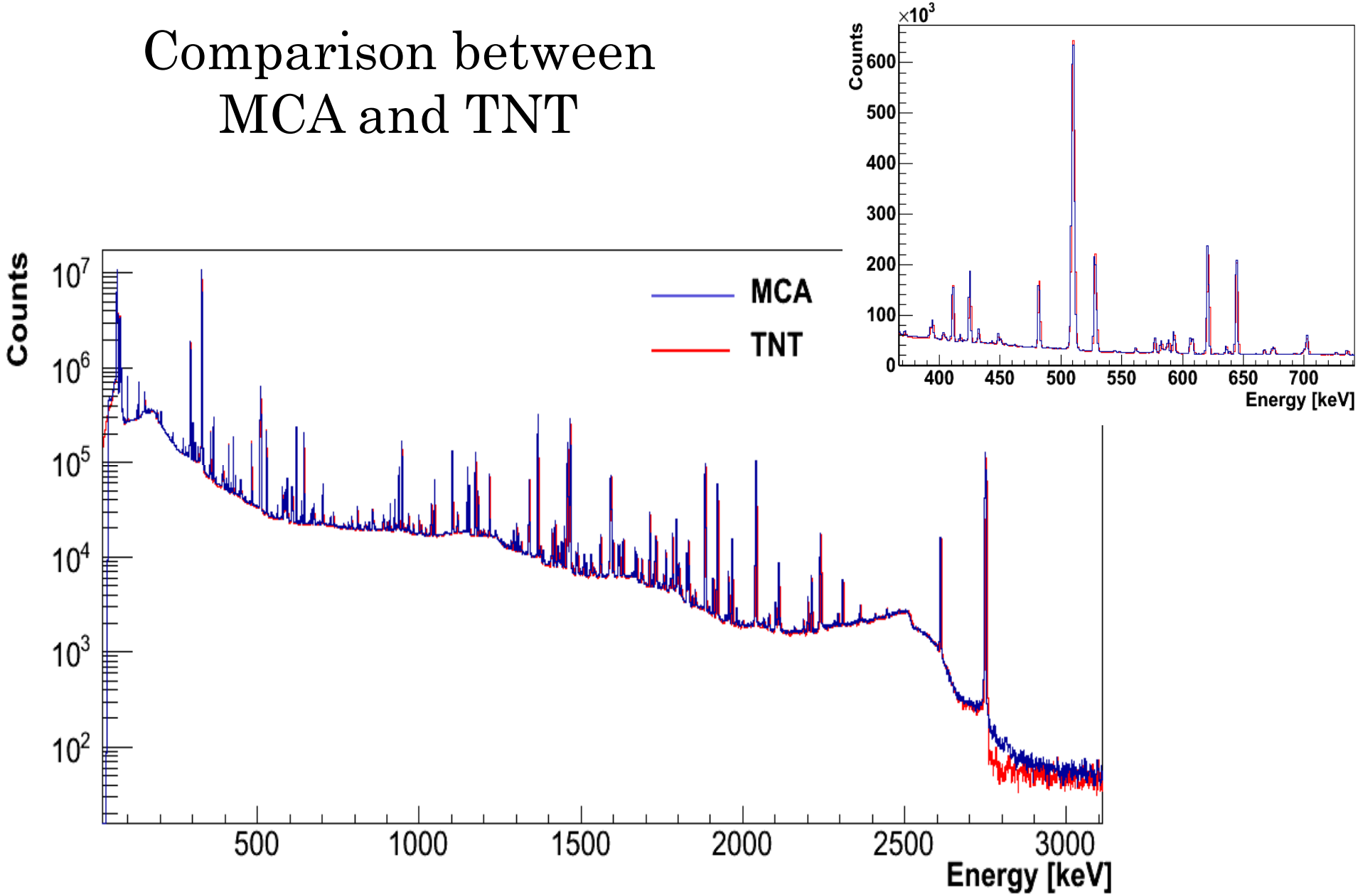
TNT cards:

- trigger less acquisition system
- 4 channels @ 100Mhz
- Trapezoidal filter for energy reconstruction

MultiChannel Analyzer (MCA)

- Shaping time : 4µs
- MAESTRO MCA Emulation Software

# Comparison between MCA and TNT

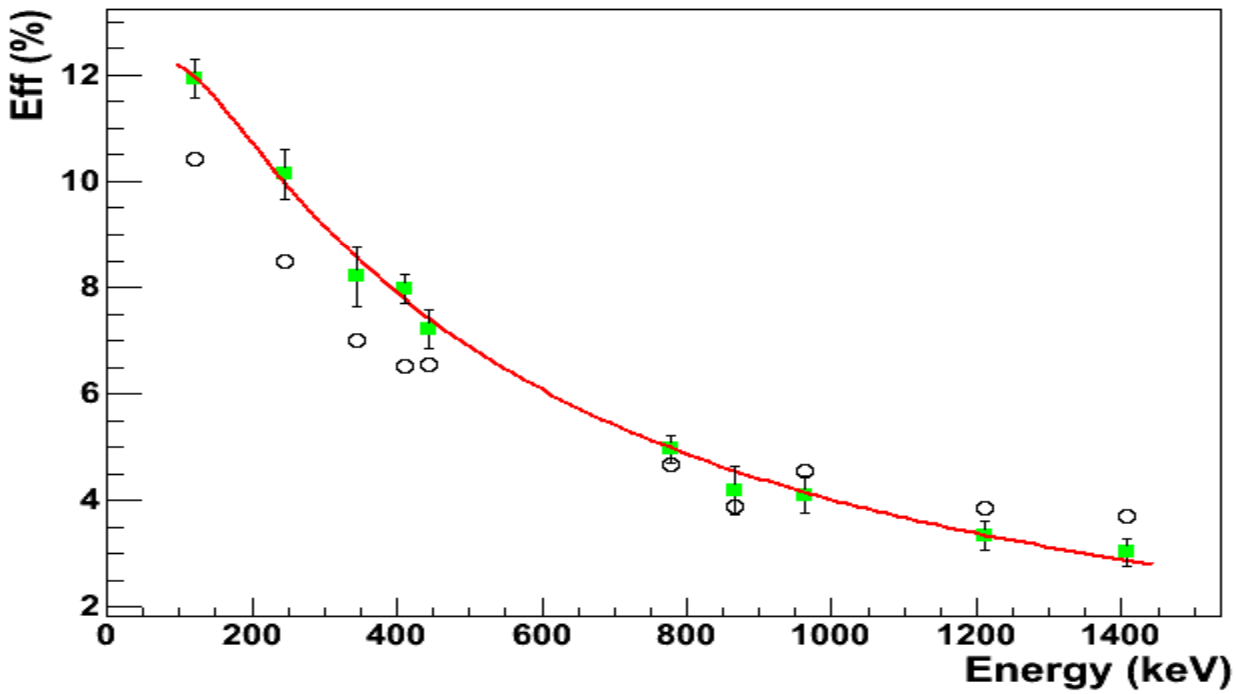



Activation spectra@ 28 MeV

# HPGe efficiency

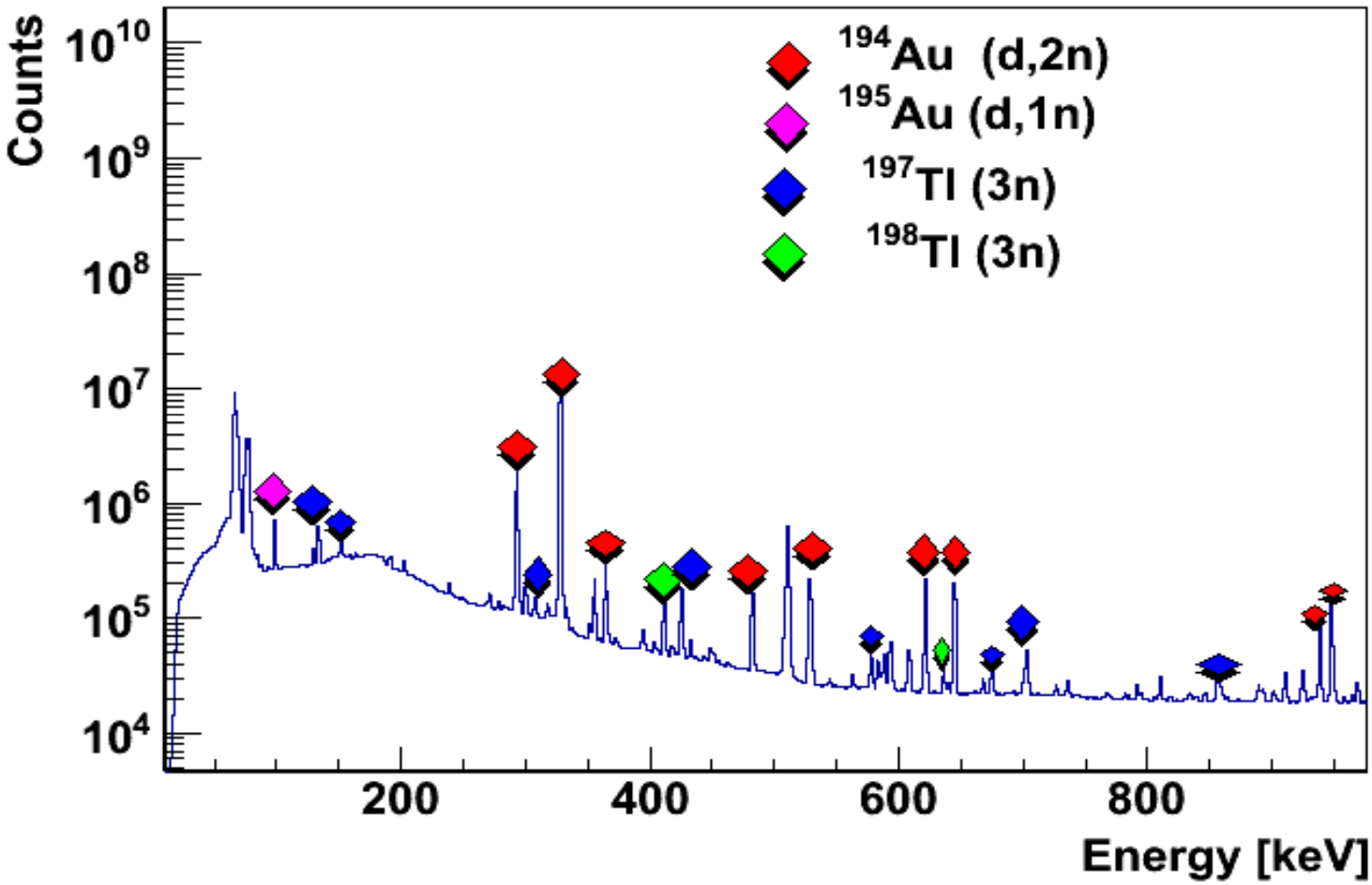
- GEANT 4 simulation for correcting summing effects

$^{152}$Eu source @ 1cm distance




- For each nucleus produced the correction factors were different (depending on the intensity of the gammas emitted in coincidence)

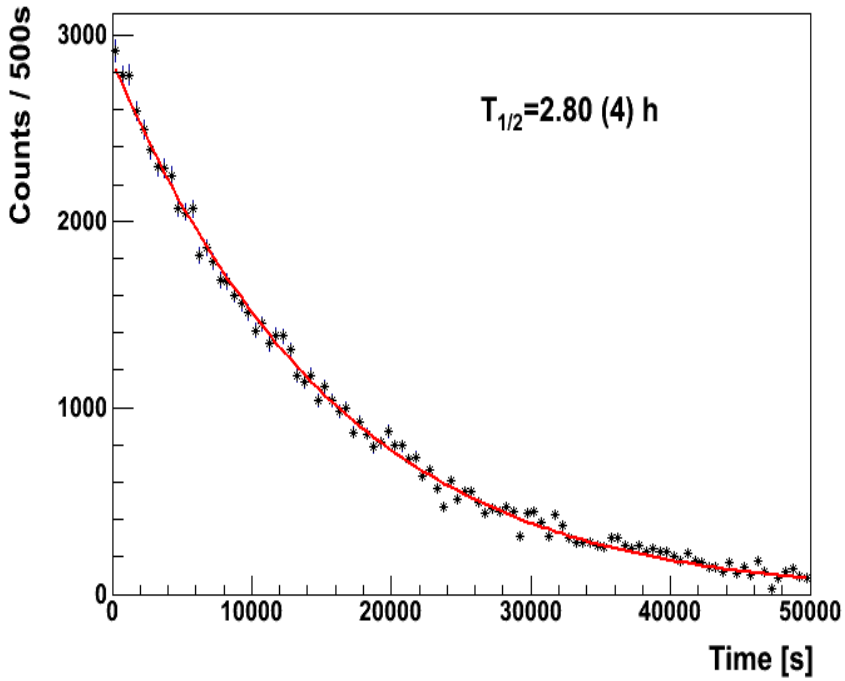
# Data treatment



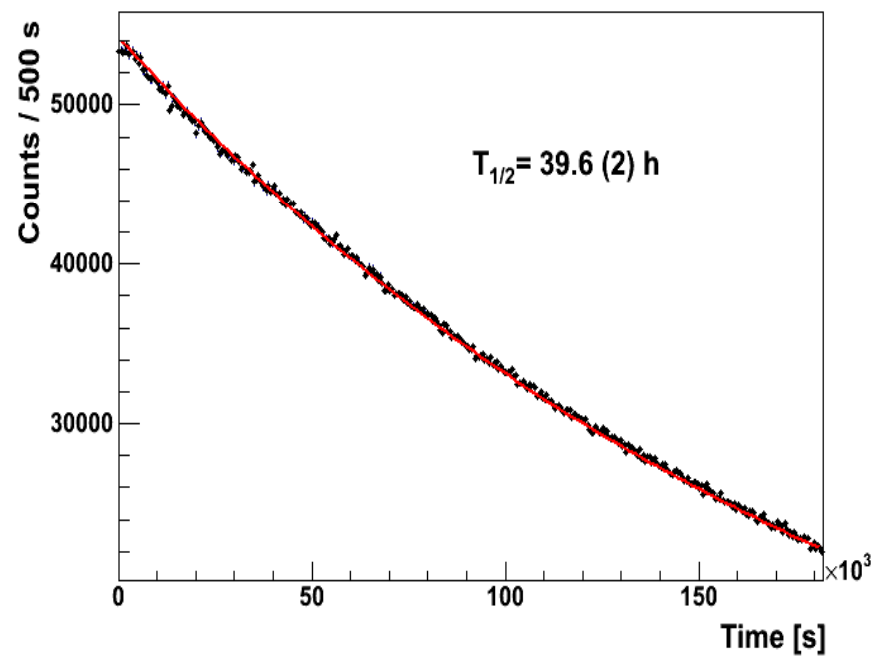

Activation spectra@ 28 MeV

# Time spectra

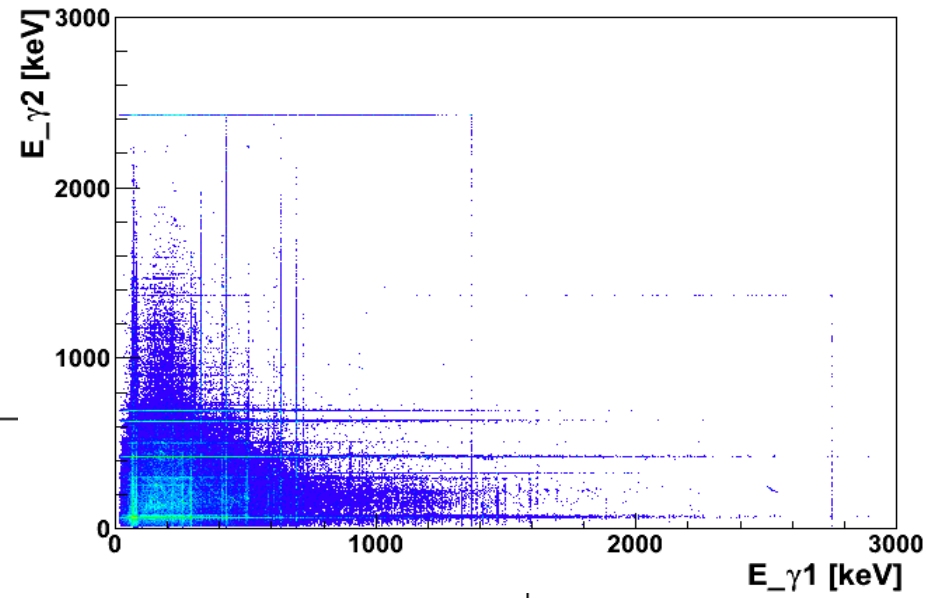
- $^{197}$Tl decay (3n)

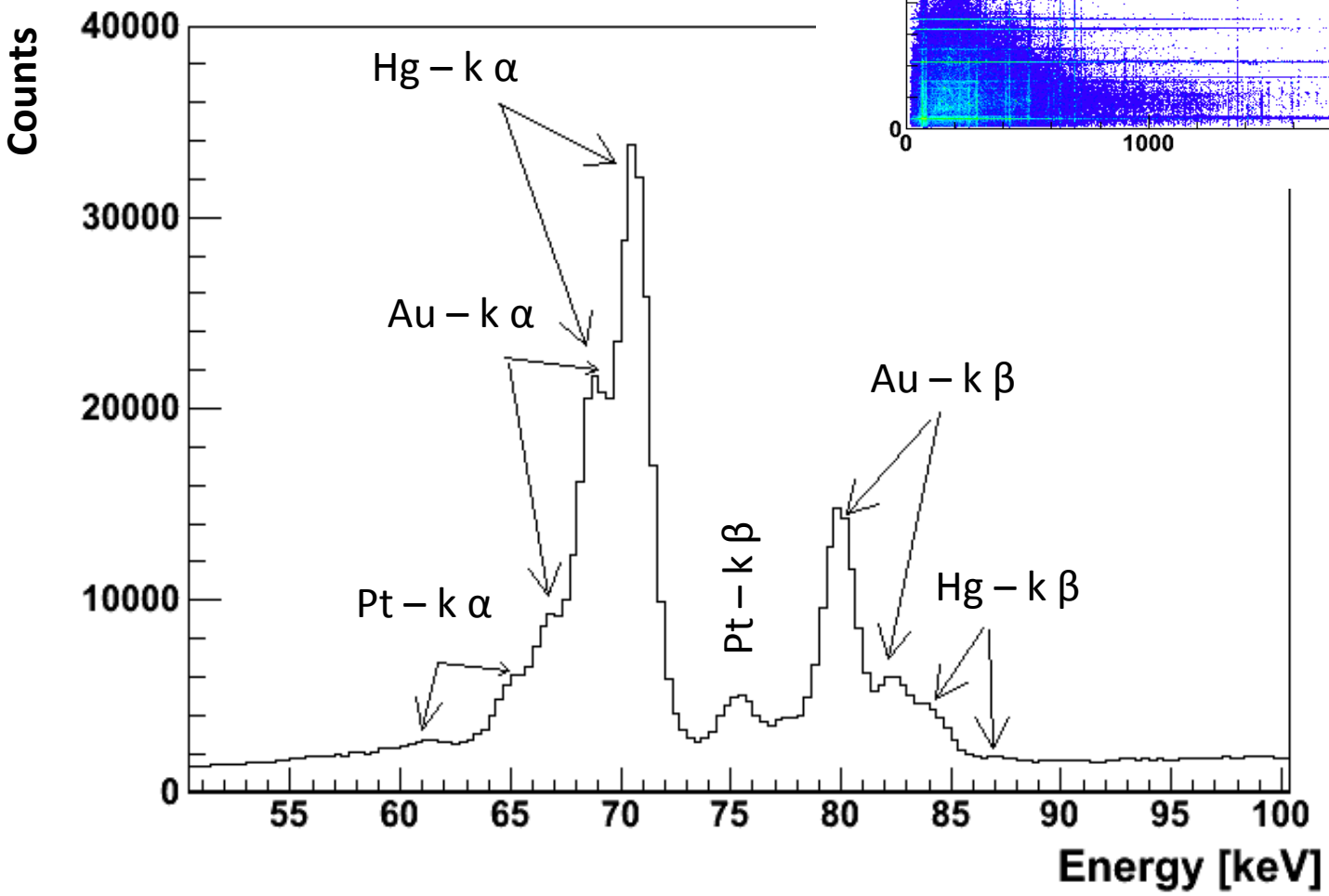



- $^{194}$Au decay (1α2n)



# Alternative method: coincidences with X-rays



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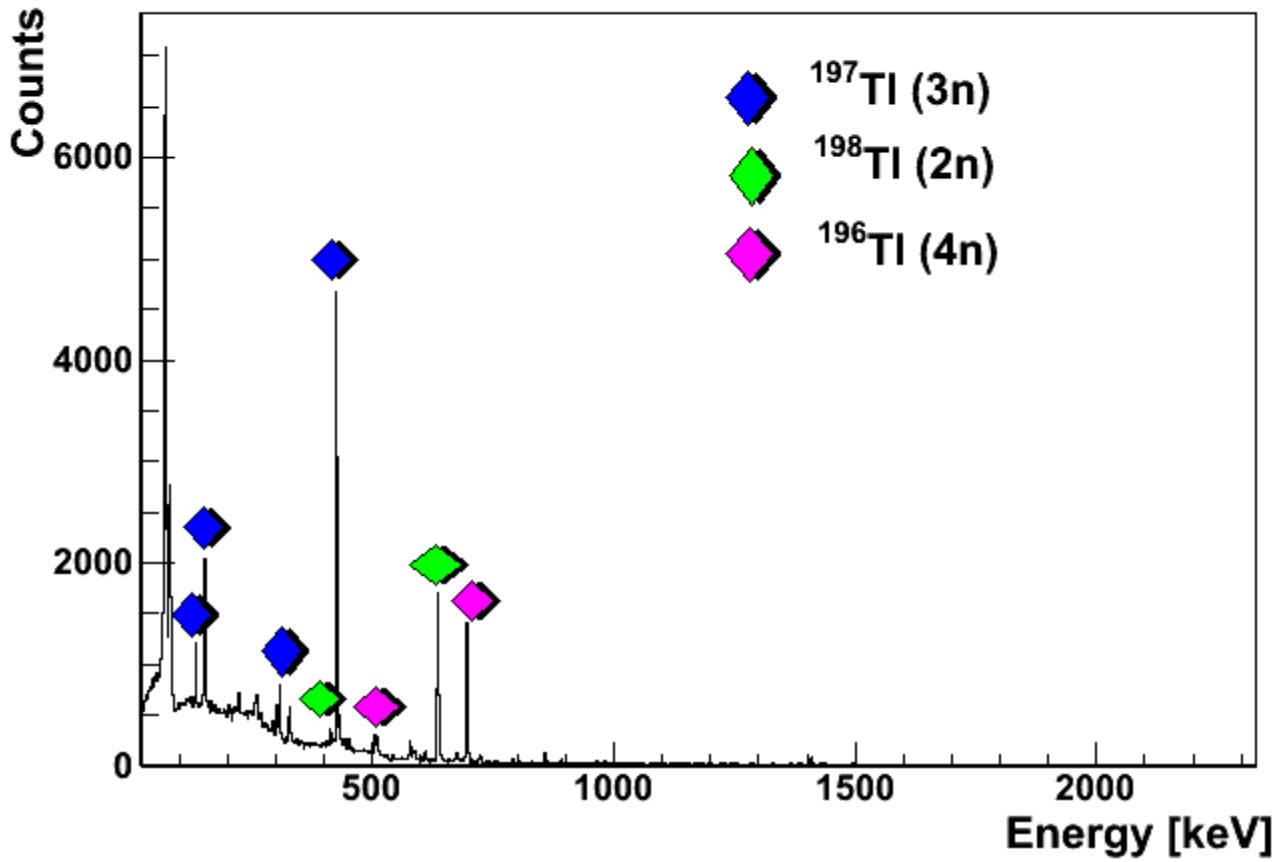
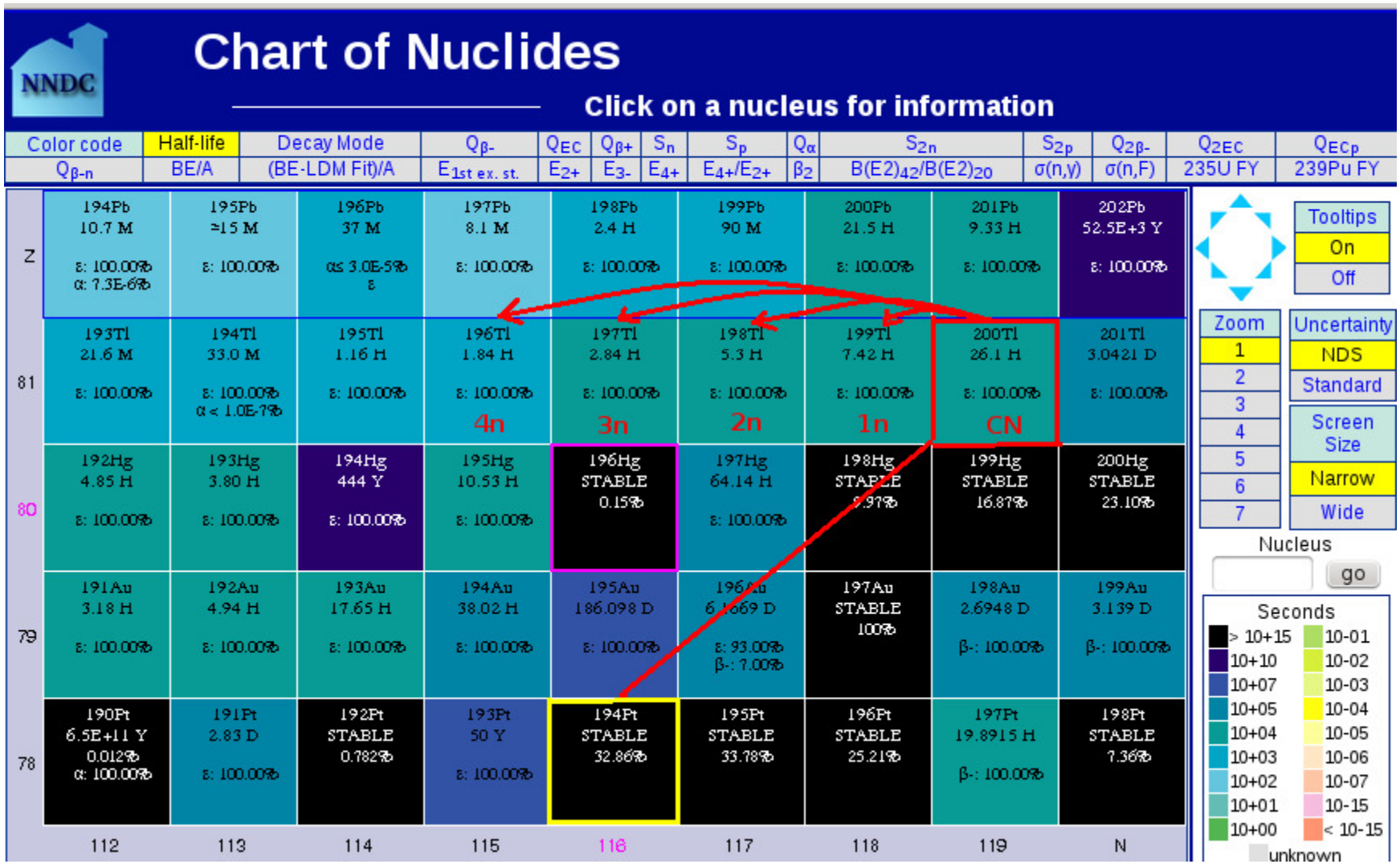


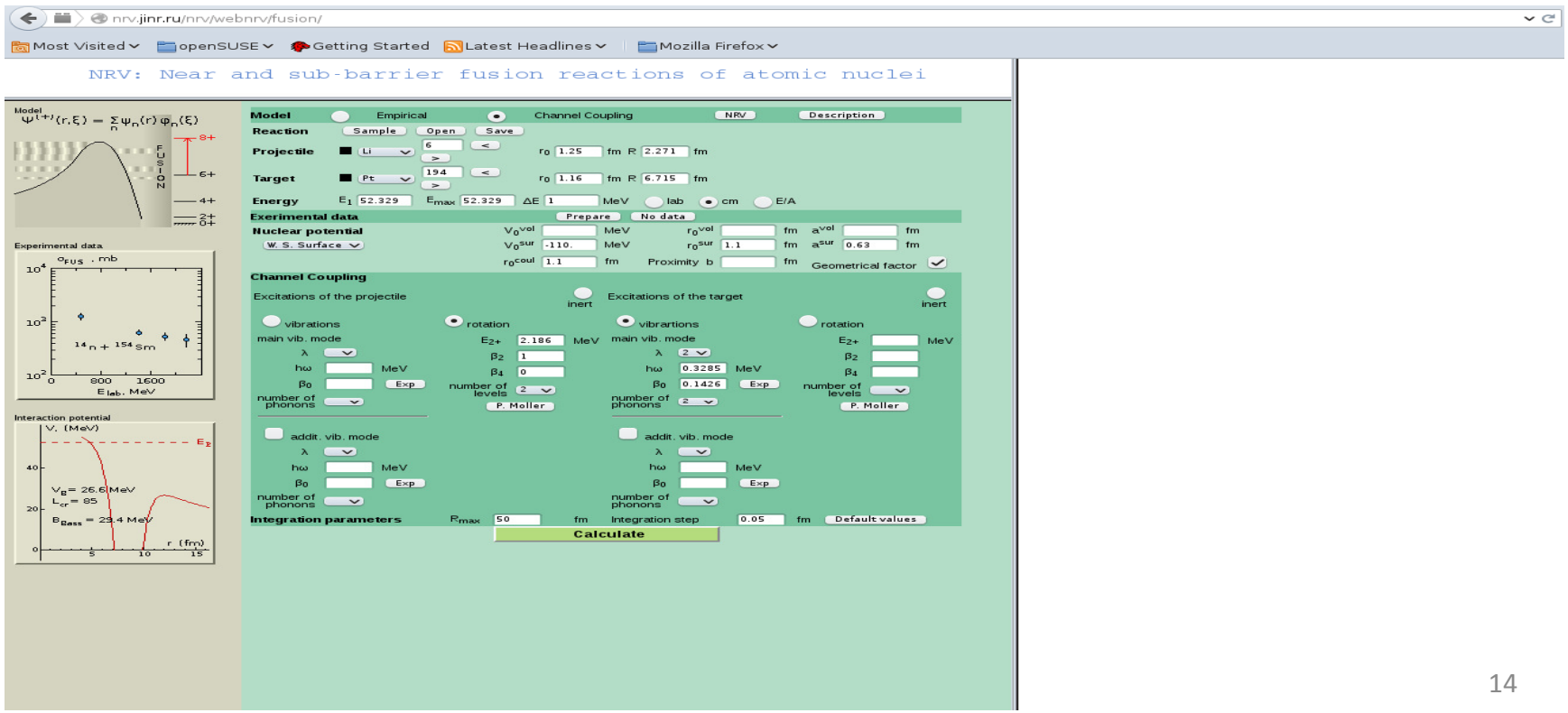
# Results and discussion



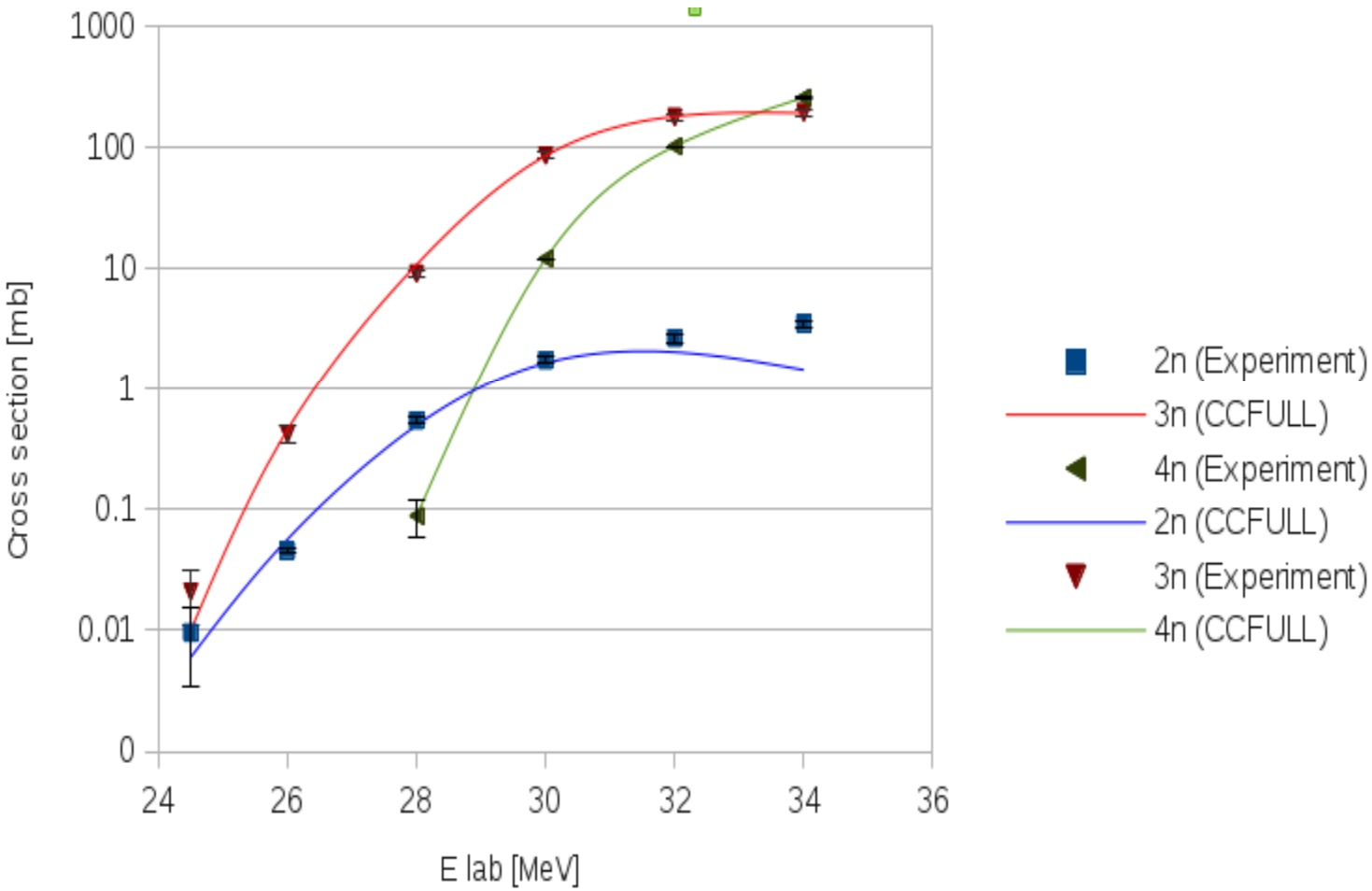
# Results and discussion

Coupled channel calculations (CCFULL code)

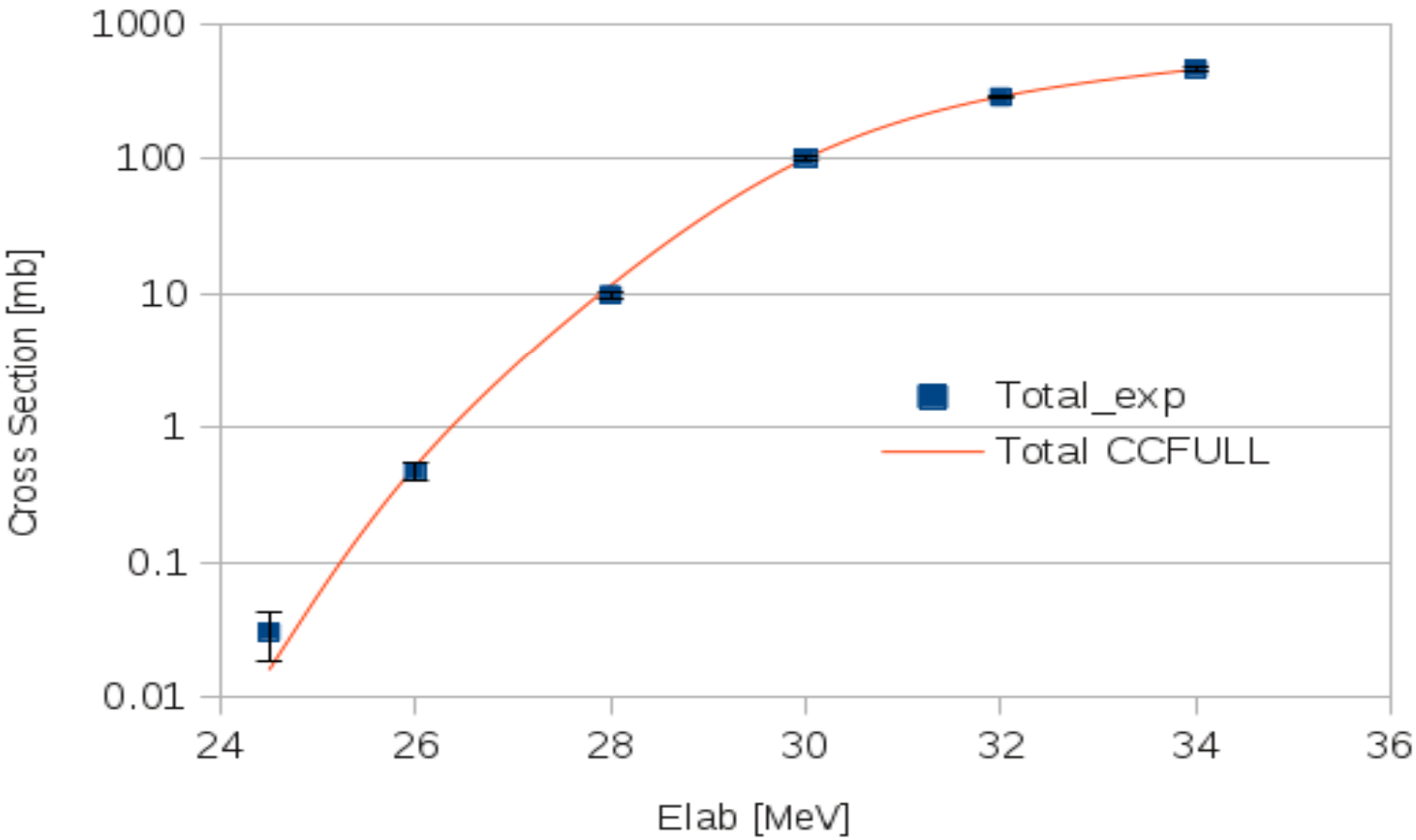
- $V_0$=110 MeV
- $r_0$=1.1 fm
- $a_0$=0.63 fm
- Target excitations (E2 transition, $E_x$=0.328 MeV & β=0.14)
- Graphical interface offered by the *nrv.jinr.ru* website:



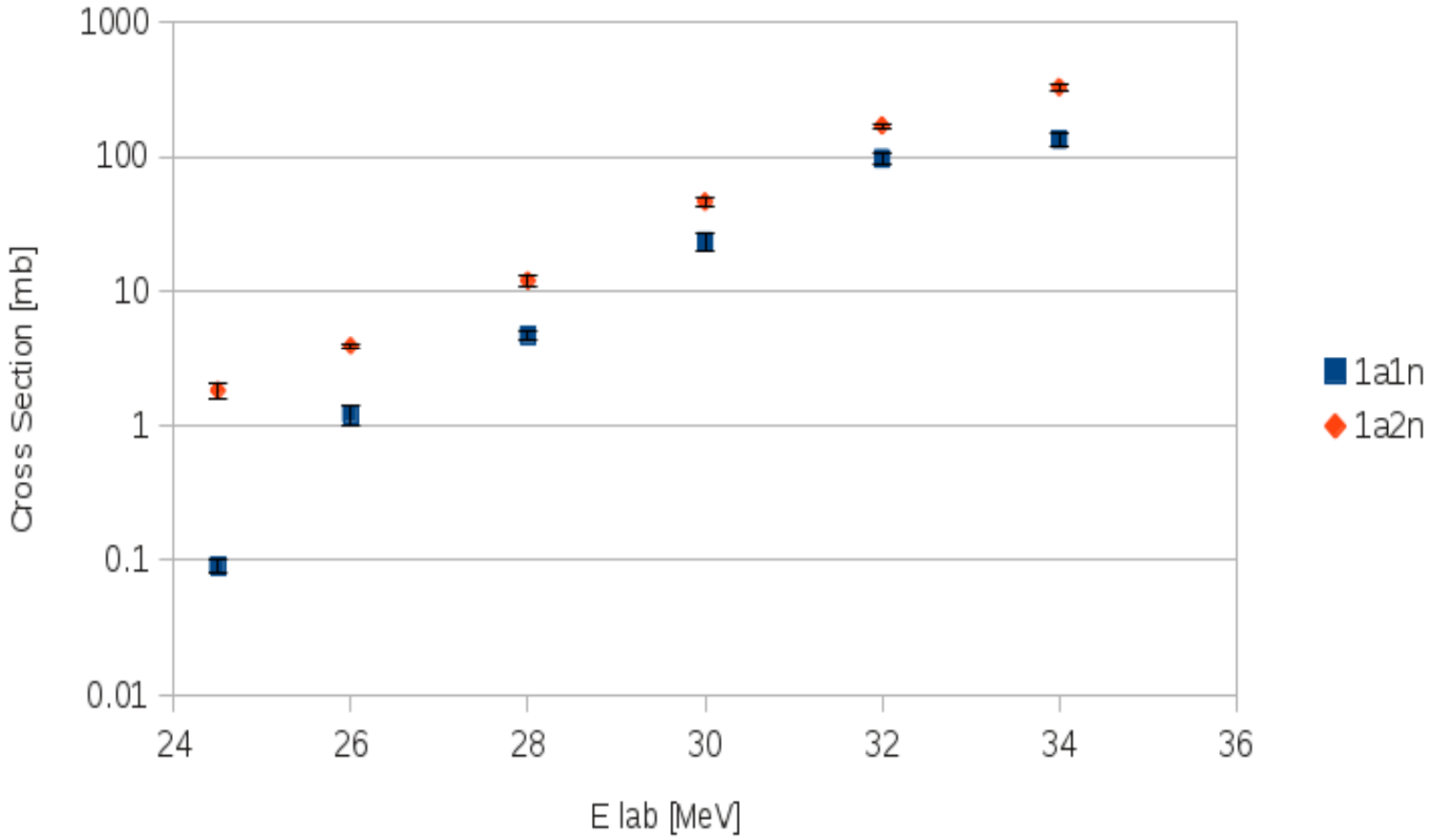
# Fusion evaporation channels

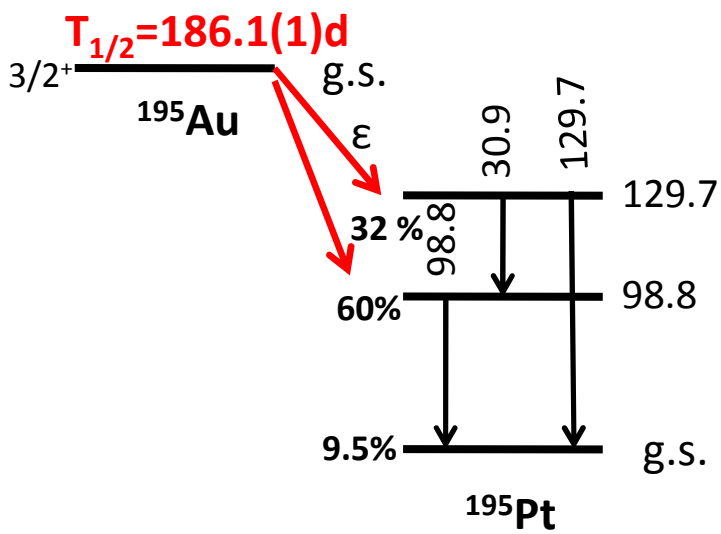


# Total fusion cross section



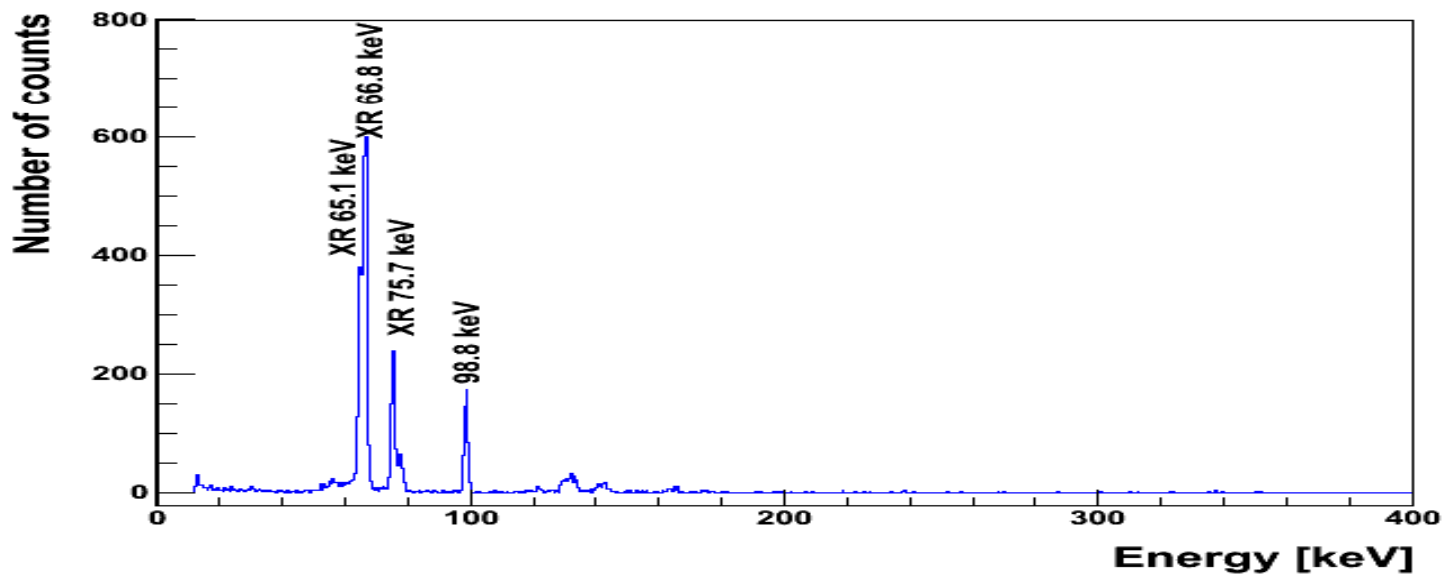
# Breakup fusion cross section (d-capture)





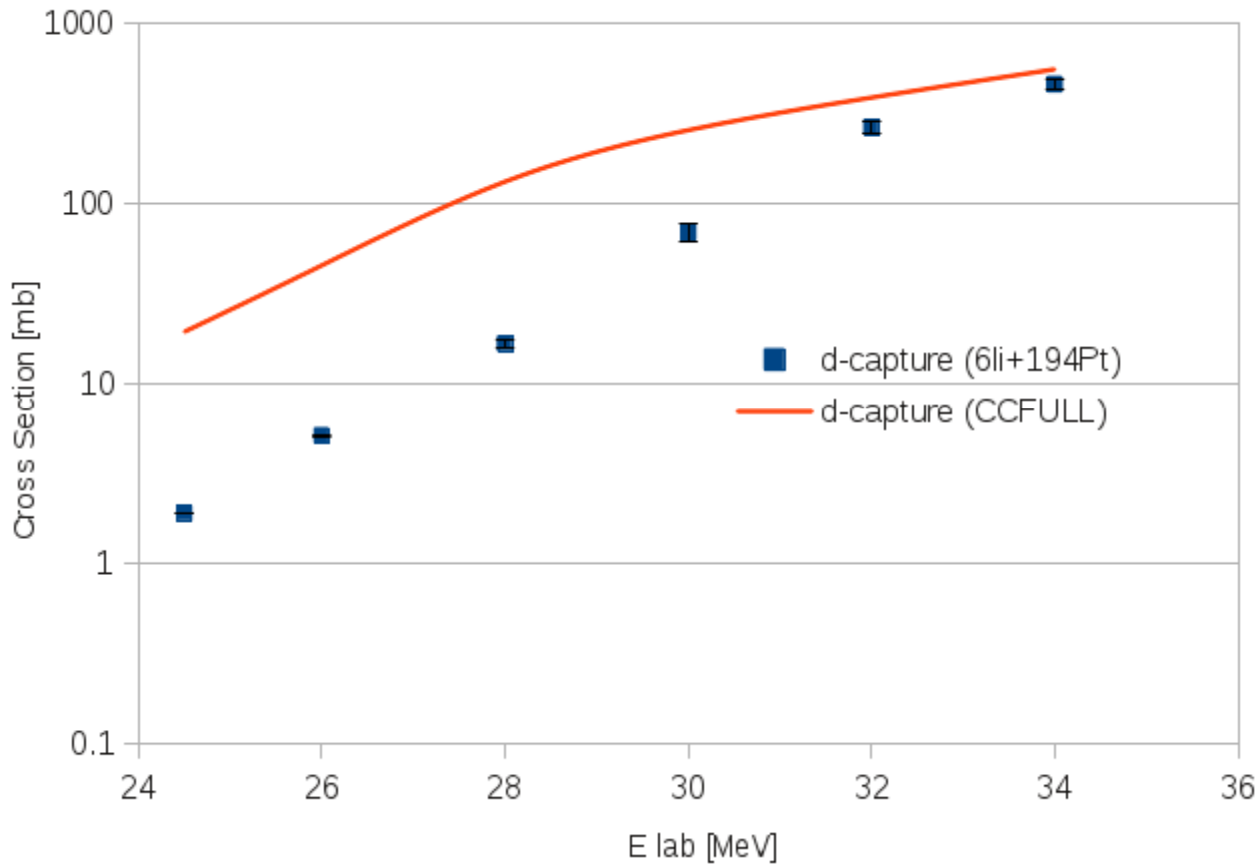

# The particular case of (1α1n) evaporation channel

γ ray spectrum recorded in Unirea Salt Mine Laboratory (208m underground)



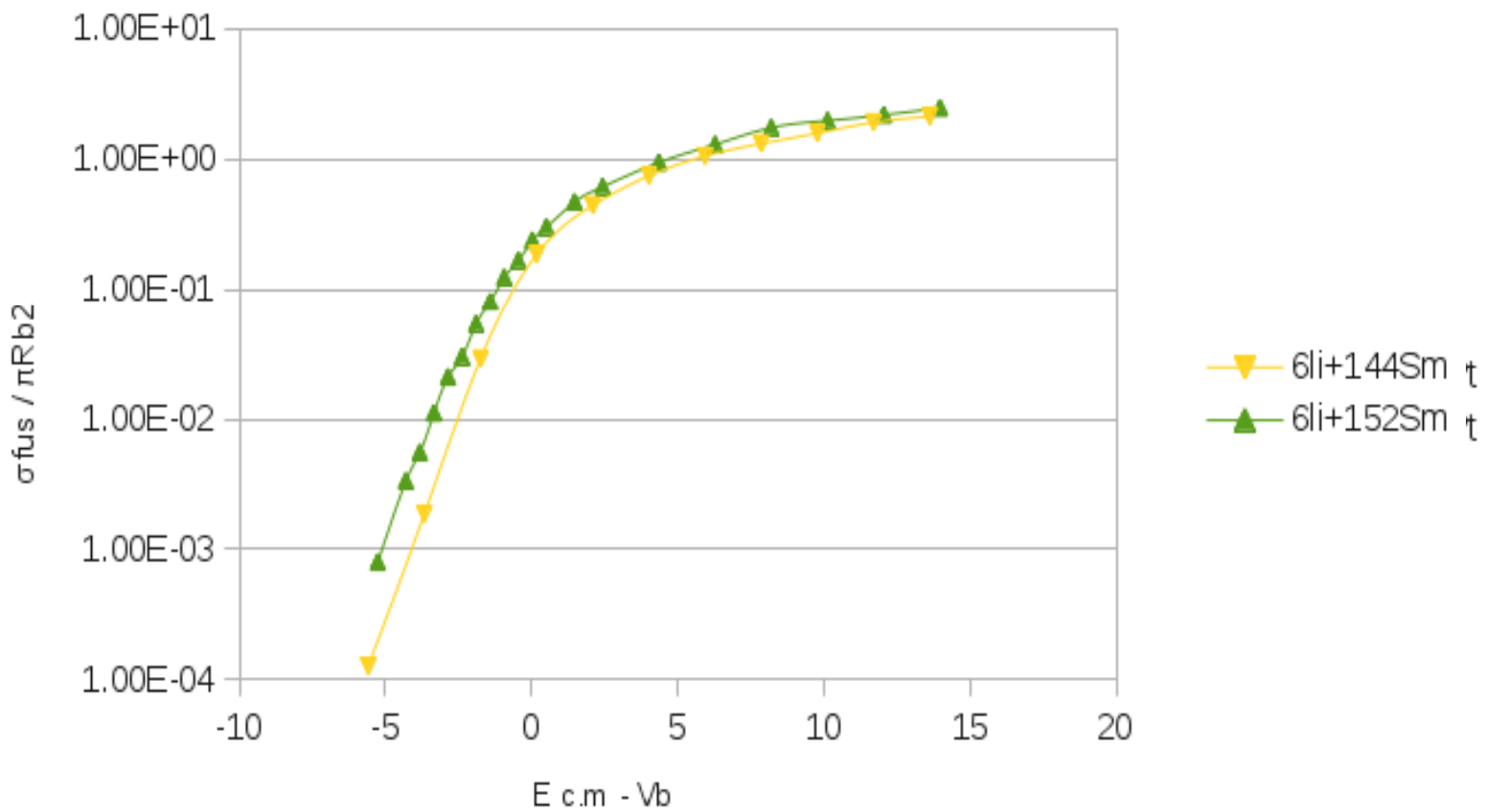

- Time elapsed from the activation experiment: **723 days**!
- Measurement duration: **3250 s**!
- Ultra-Low background conditions
- Summing effects

# d-capture cross section




*CCFULL calculation considering a $^{2}D$ beam on a $^{194}Pt$ target at incident energies equivalent to 1/3 of the $^{6}Li$ energy

# $^{6}$Li fusion evaporation reactions




A. Shrivastava *et al.*, Phys. Rev. Lett. 103 (2009), 232702
P.K. Rath *et al.*, Phys. Rev. C 79 (2009), 051601(R)
P.K. Rath *et al.*, Nucl. Phys. A 874 (2012), 14-31

# $^{194}$Pt γ-soft nature

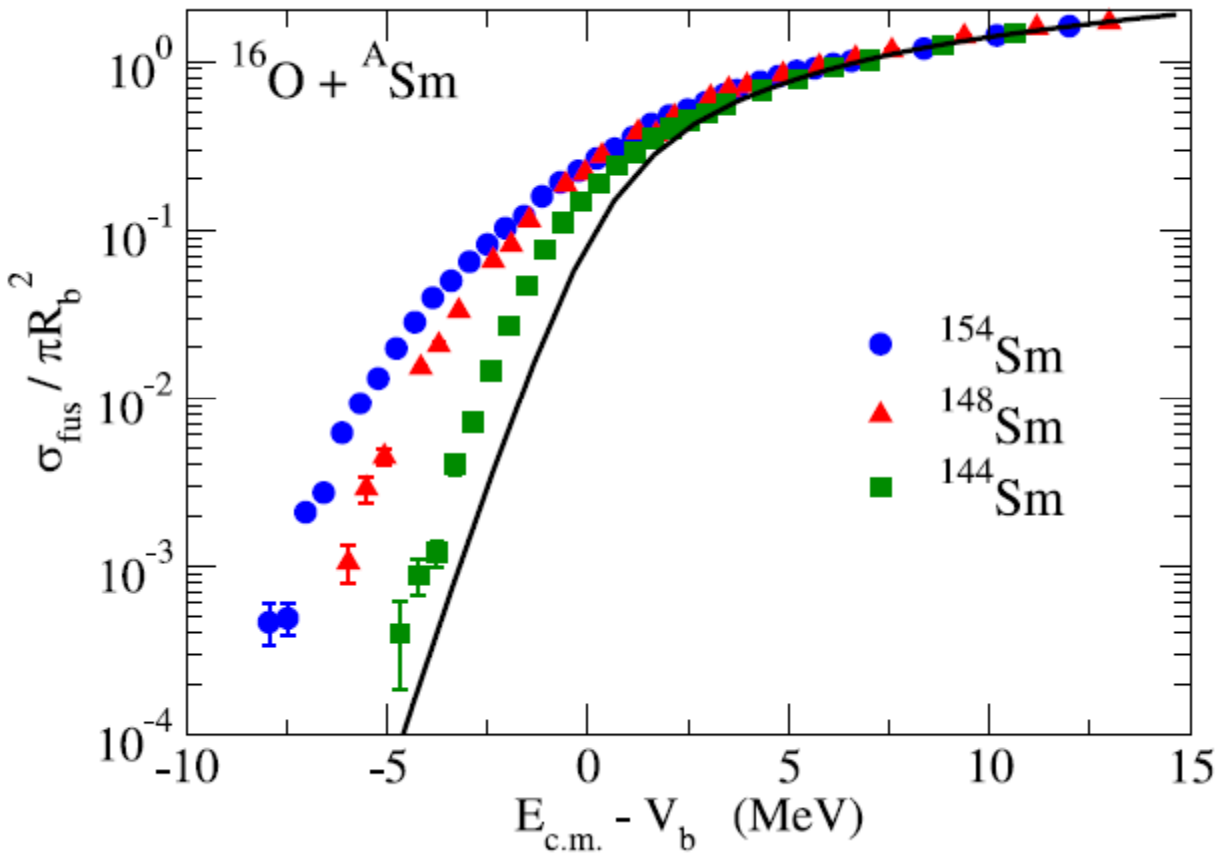
PHYSICAL REVIEW C VOLUME 57, NUMBER 1 JANUARY 1998

## Evolution of nuclear structure in O(6)-like nuclei

N. V. Zamfir,[1,2,3,4] W.-T. Chou,[5] and R. F. Casten[1]
[1]*WNSL, Yale University, New Haven, Connecticut 06520*
[2]*Brookhaven National Laboratory, Upton, New York 11973*
[3]*Clark University, Worcester, Massachusetts 01610*
[4]*Institute of Atomic Physics, Bucharest-Magurele, Romania*
[5]*National Tsing Hua University, Hsinchu, Taiwan, Republic of China*
(Received 4 August 1997)

The evolution of nuclear structure along the Xe and Ba isotopes with $N<82$ is studied in comparison with that in the Pt-Os isotopes and with interacting boson approximation calculations. As is well known, the Pt isotopes from $^{188-196}$Pt exhibit a stable structure very close to O(6), the lighter Pt isotopes and the Os nuclei evolve towards a rotor, and the heaviest Pt nuclei, $^{198,200}$Pt, show a tendency towards vibrational character. In contrast, we show that the Ba nuclei are best described by a trajectory from U(5) towards SU(3) that passes through an intermediate structure that resembles O(6) for $N\sim 72-76$. The Xe appears to evolve from U(5) to O(6)-like. [S0556-2813(98)01401-0]

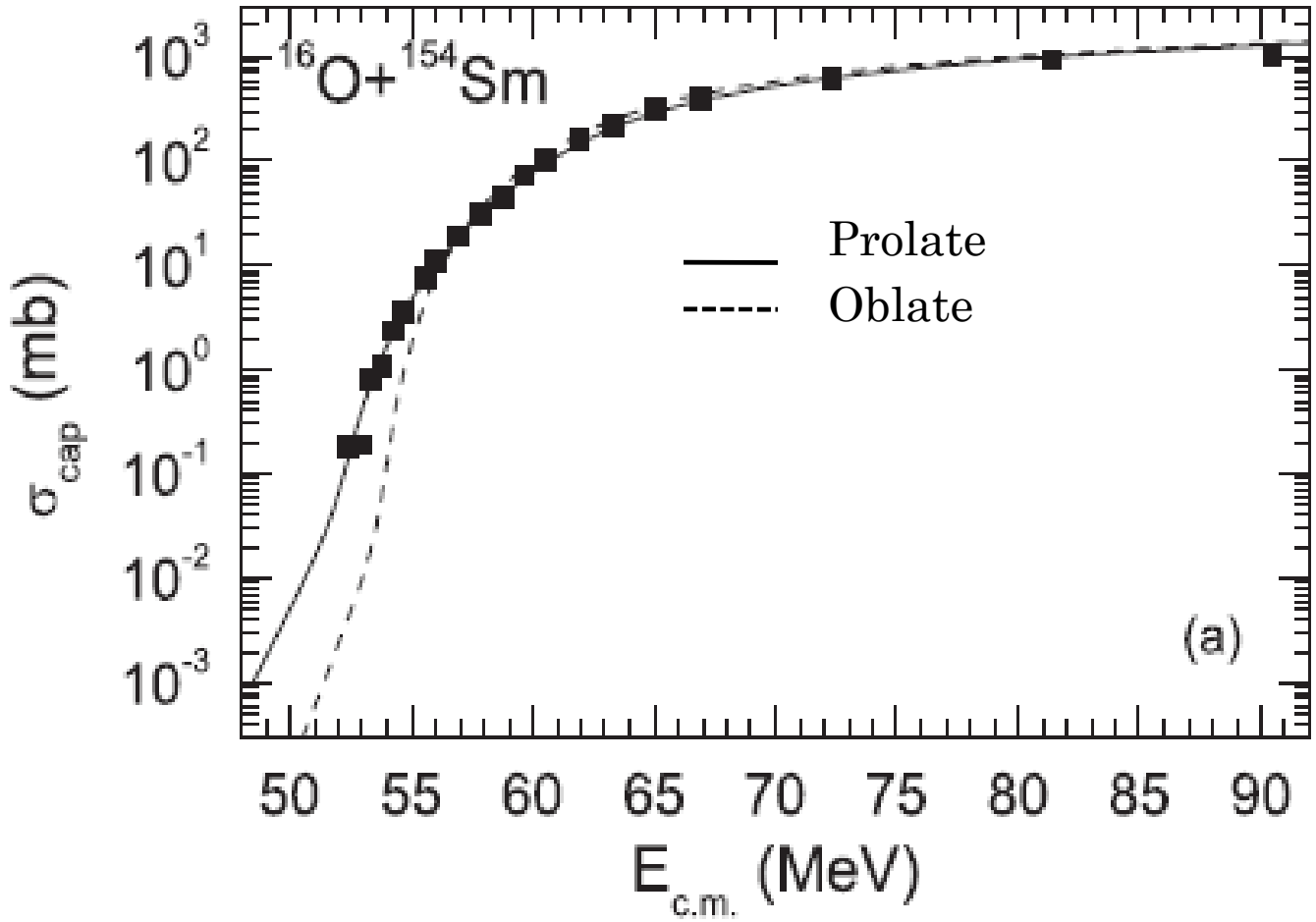
# The case of Sm isotopes




In order to remove the target dependence the cross section are were divided by $\pi Rb^2$ , and the beam energies are represented with respect to the Coulomb barrier height, $V_b$.

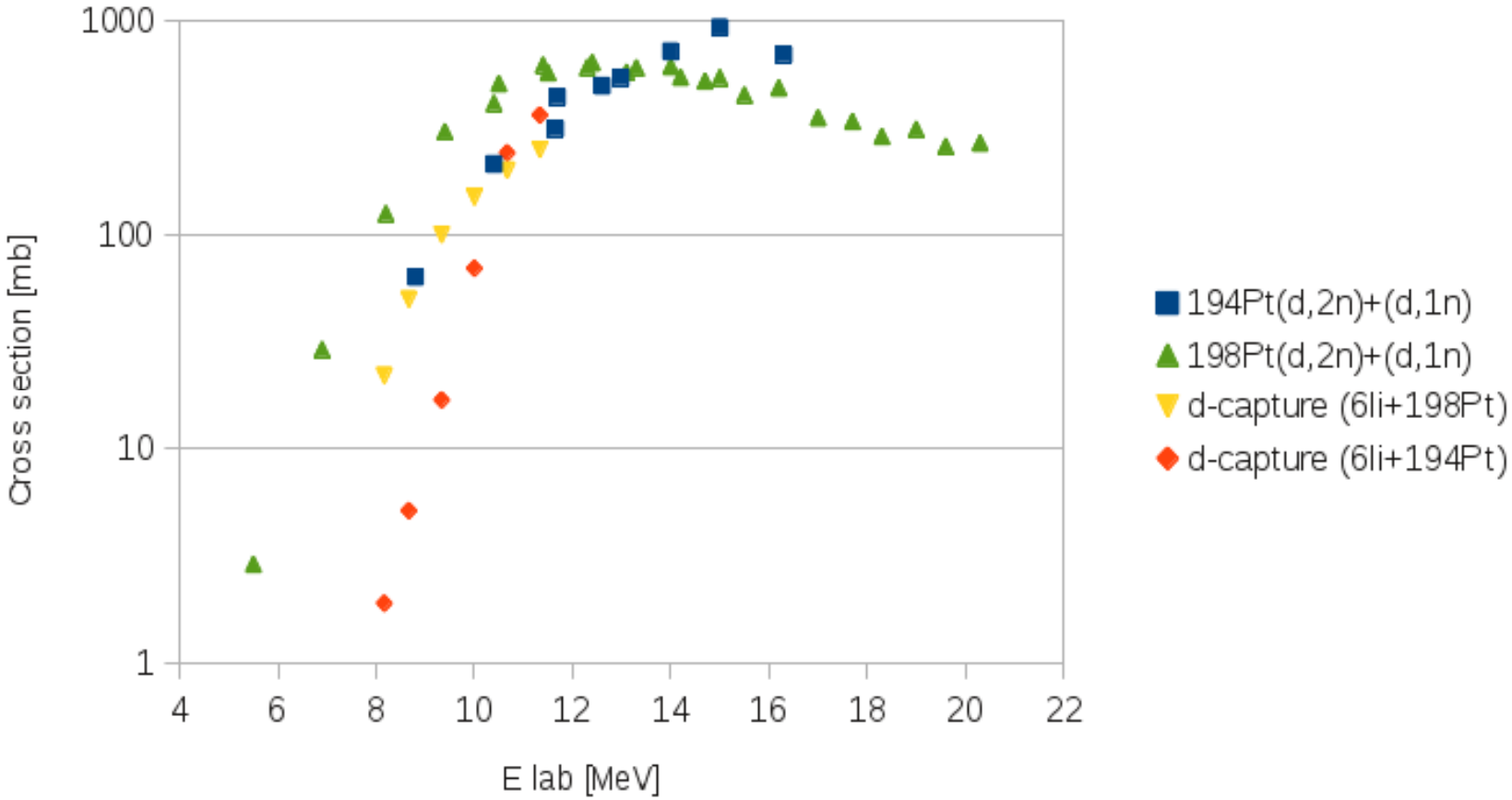
J.R. Leigh *et al.*, Phys. Rev. C 52 (1995), 3151

Quantum diffusion approach(QDM) .
The role of prolate and oblate deformation in capture cross section at sub-barrier energies




V.V. Sargsyan et al., Phys. Rev. C 85 (2012), 017603

# d-capture on $^{198}$Pt & $^{194}$Pt





F. Tarkanyi *et al.*, Radiochimica Acta 92 (2009), 223
A.A. Kulko *et al.*, Phys. Of Particle and Nuclei Letters 9 (2012), 505-507
A. Shrivastava *et al.*, Phys. Rev. Lett. 103 (2009), 232702

# Conclusions

- The fusion evaporation cross section is well reproduced by the CCFUS calculations (target excitations included)
- d-capture cross section deviates from the theoretical predictions (for a d+$^{194}$Pt reaction). Influence of the breakup probability at Coulomb barrier energies?
- The difference between the $^{194}$Pt and $^{198}$Pt data due to the different intrinsic structure of the target nuclei.