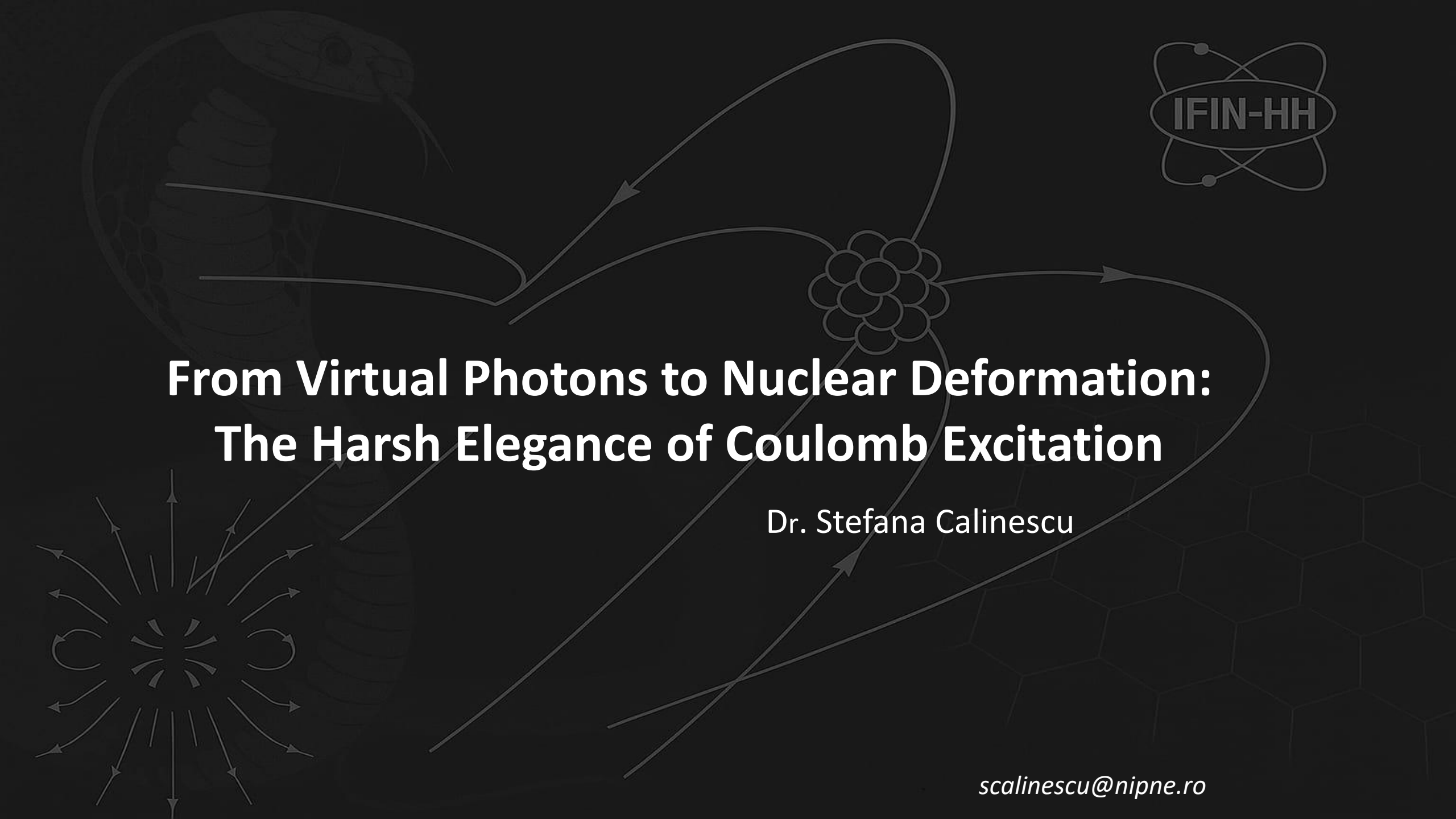


From Virtual Photons to Nuclear Deformation: The Harsh Elegance of Coulomb Excitation

Dr. Stefana Calinescu

scalinescu@nipne.ro

Introduction to Coulomb Excitation

C.E. is a fundamental tool in nuclear structure physics, enabling precise determination of electromagnetic transition probabilities in nuclei. By using the well-known electromagnetic field generated during the scattering of a projectile on a heavy target, one can selectively excite low-lying collective states without invoking nuclear reactions.
The process of Coulomb excitation arises from the time-dependent interaction between the electromagnetic field of the projectile and the target nucleus. In semi-classical theory, this field acts as an external perturbation that can promote the nucleus to an excited state via virtual photon exchange. The excitation cross-section depends on the impact parameter, the energy of the projectile, the multipolarity of the transition etc. Theoretical treatment often employs the first-order perturbation theory or coupled-channels formalism, the latter becoming necessary when multiple-step excitations or reorientation effects are non-negligible.

- Coulomb excitation = electromagnetic process → populates nuclear states via interaction with EM field of a target nucleus.
- Ideal for probing collectivity in even-even nuclei (E2 transitions, quadrupole deformation).
- Especially useful at intermediate energies (~50–100 MeV/u) using inverse kinematics.
- Objective: extract B(E2; $0^+ \rightarrow 2^+$) values to quantify deformation and collectivity.
- Motivation: Understanding the shell evolution, test nuclear models, benchmark effective charges.
- Cross-section proportional to $|\langle 2^+||E2||0^+\rangle|^2 = B(E2)$.
- First-order perturbation → valid when nuclear interaction is negligible (safe angles).
- Formula: $d\sigma/d\Omega \propto B(E2) \times (Z_t^2 / b^4) \times$ [angular factor]

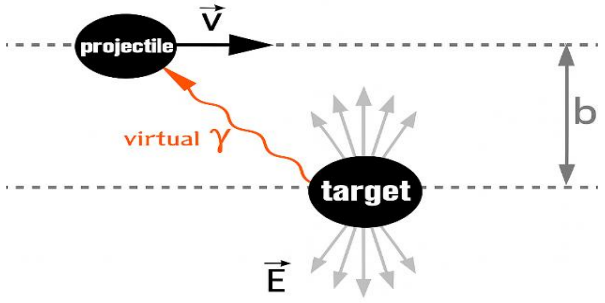
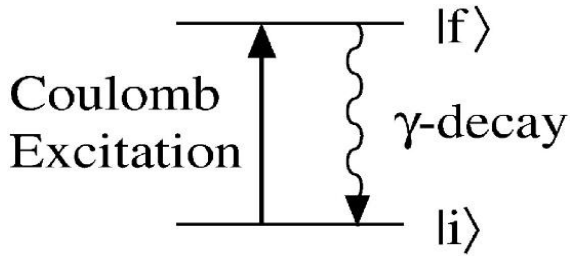


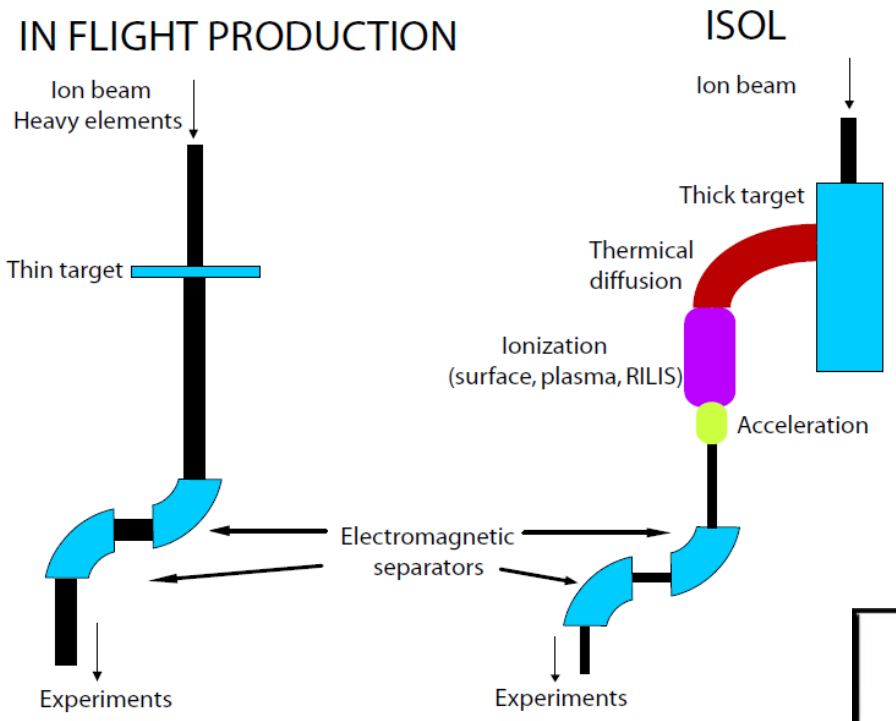
Illustration of a projectile being scattered in the Coulomb field of the target nucleus. For a given beam velocity β, the impact parameter b depends on the scattering angle θ.



Schematic of the first-order Coulomb excitation of a nucleus from an initial state |ito a final bound state |f> and its subsequent γ-decay.

T. Glasmacher et all, Annu. Rev. Nucl. Part. Sci. 1998.

Coulomb excitation at intermediate energies



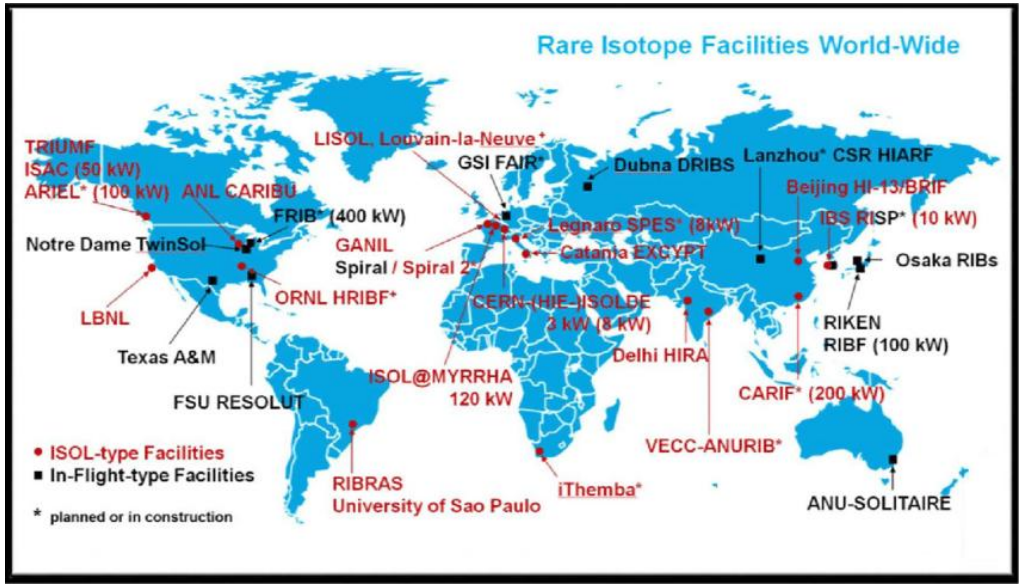
The two main methods for the exotic beam production: (left) the in-flight technique /fragmentation and (right) the ISOL-technique.

ISOL

- ➔ low beam energy with high intensity
- ➔ Thin secondary target
- ➔ Safe coulex

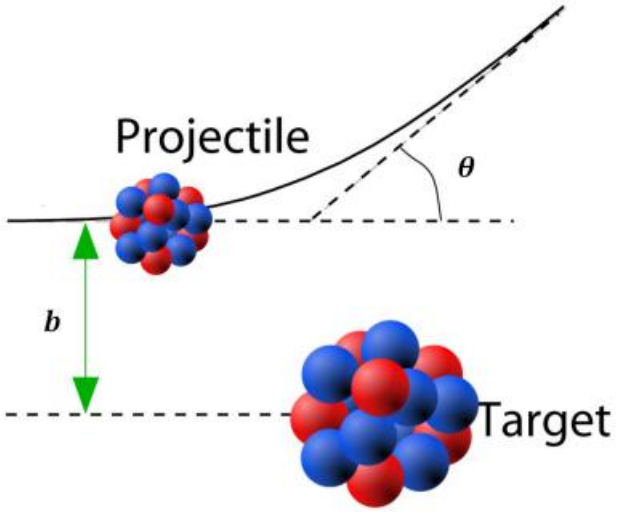
In-Flight

- ➔ High beam energy with low intensity
- ➔ Thick target
- ➔ "dangerous" coulex



Experimental Considerations at Intermediate Energies

- Use of inverse kinematics: heavy radioactive beam impinges on stable, high-Z target.
- Projectile fragmentation for beam production (e.g., via Be or C targets).
- Thin targets (~1–5 mg/cm²) ensure minimal energy loss, but decrease **σ** ➔ thick targets (~200 1–5 mg/cm²)
- Safe-angle concept: minimum scattering angle to avoid nuclear contributions, defined via distance of closest approach.



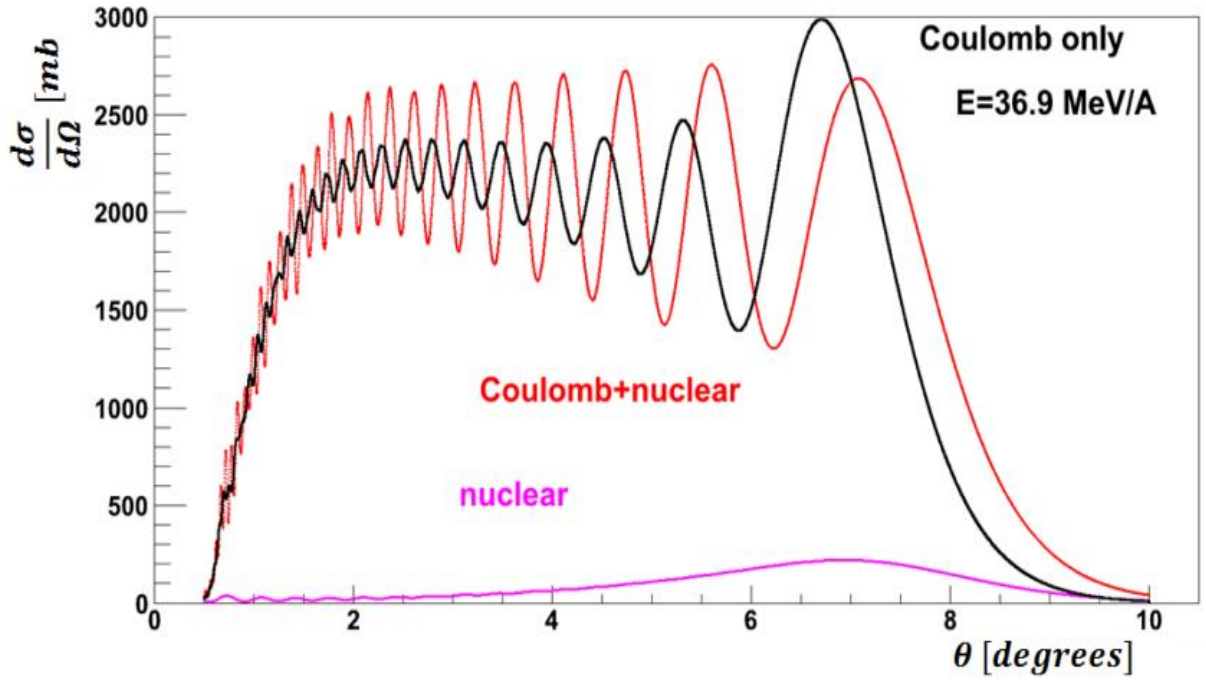
$$b_{safe} = R_p + R_t + 6 + \frac{\pi a}{2\gamma}$$

$$R_{p,t} = 1.28A_{p,t}^{\frac{1}{3}} - 0.76 + 0.8A_{p,t}^{\frac{-1}{3}}$$

$$\theta = \frac{2Z_pZ_te^2}{m_0c^2\beta^2b\gamma},$$

Separation of Coulomb and Nuclear Contributions

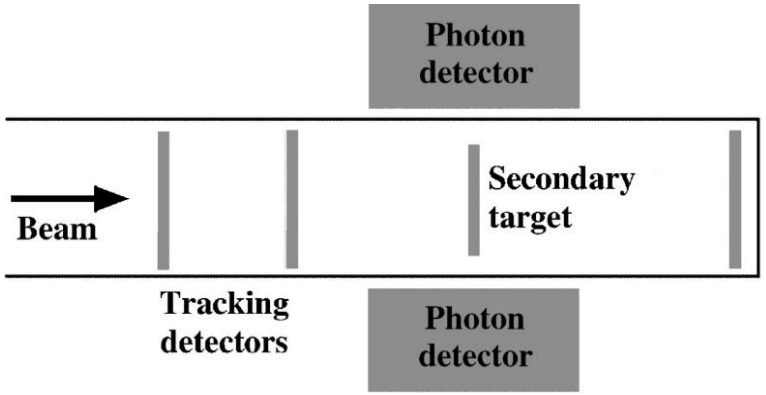
- At intermediate energies, nuclear and Coulomb processes overlap—careful data selection is crucial.
- Use of angular cuts: analyze only events at or beyond "safe angle" to minimize nuclear contamination.
- Nuclear contribution not strictly zero even at safe angles → must be modeled and subtracted via simulations.
- Typically, nuclear-Coulomb interference becomes non-negligible below ~1.5°–2.0°.



ECIS calculation for 46Ar+208Pb projectile-target combination using an OP for ^{40}Ar+^{208}Pb@ 44 MeV/A

➔Use of both isoscalar and isovector probes

Coulomb excitation at intermediate energies



Schematic experiment setup of a Coulomb excitation experiment.

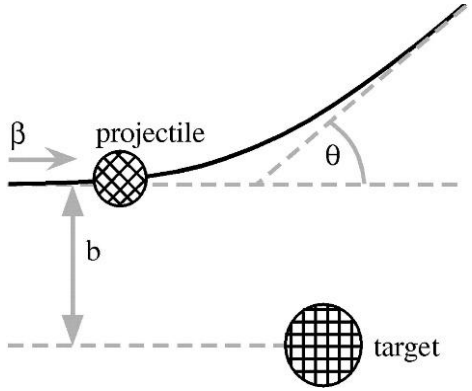
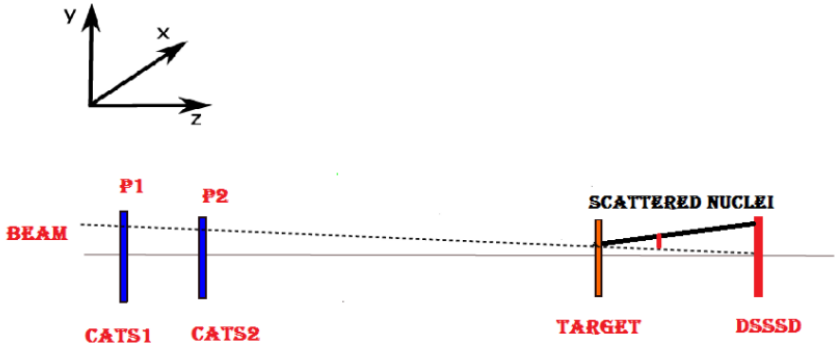


Illustration of a projectile being scattered in the Coulomb field of the target nucleus. For a given beam velocity β, the impact parameter b depends on the scattering angle θ.



➔ allows simultaneous measurements of the energy of excited bound states with respect to the ground state in exotic nuclei and of the Coulomb-excitation cross section to excite these states.

➔ The measured Coulomb-excitation cross section is a direct function of the electromagnetic matrix elements B($E\lambda$) and B($M\lambda$)

Coulomb excitation at intermediate energies

Important aspects :

1) Choice of target material

➔ **High Z target for Coulomb excitation (e.g. ^{208}Pb, ^{197}Au)**
Coulex of the target

➔ **Low Z target for measuring the nuclear cross-section**

2) Choice of target thickness

3) Choice of beam energy

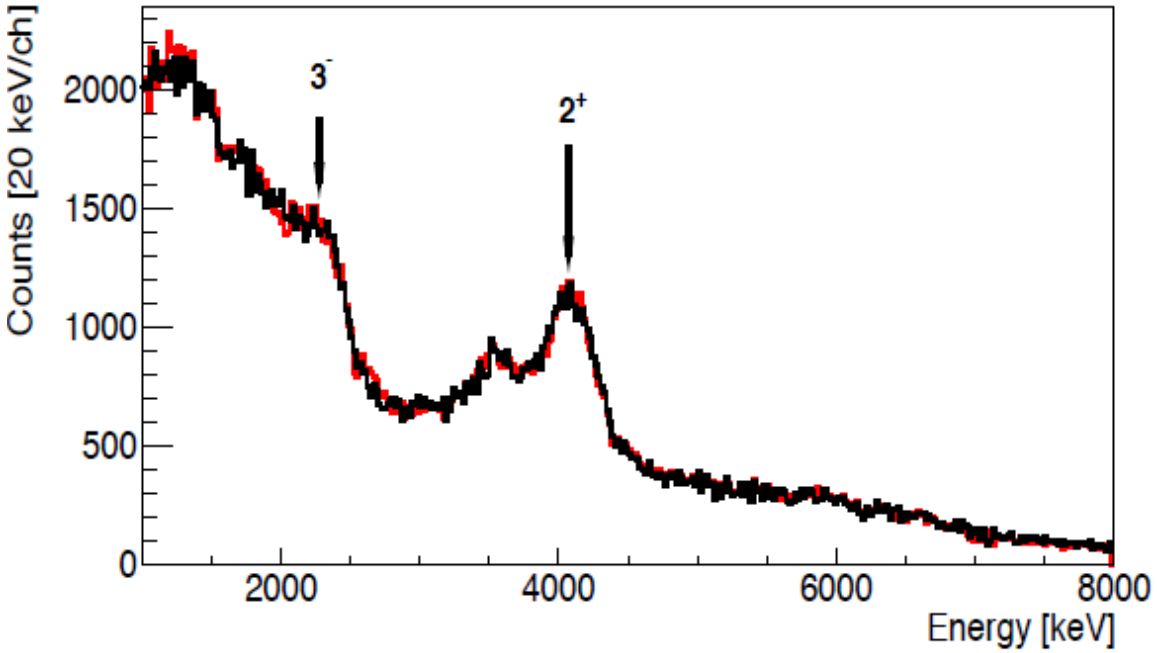
4) Choice of gamma and particle detector

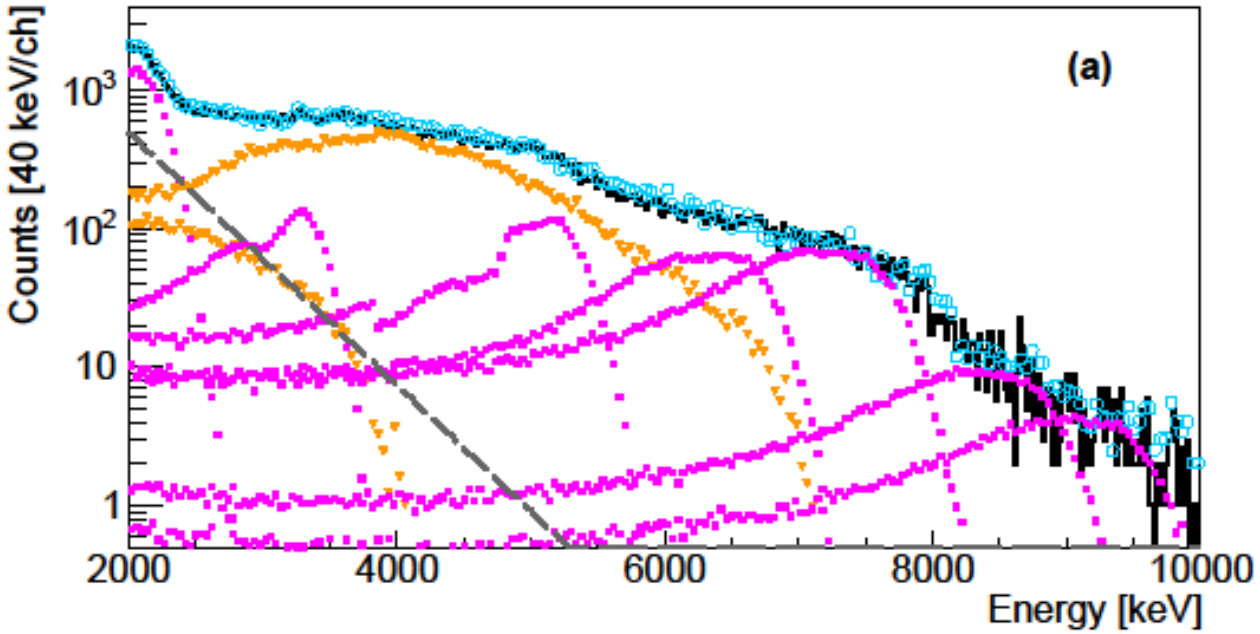
5) γ-rays are emitted in flight

6) Addback and angular distribution of γ-rays (that can induce up to 4% difference in efficiency)

7) Choice of O.P.

8) How do you know that you are right? Can you trust your measurement? How do you prove it?

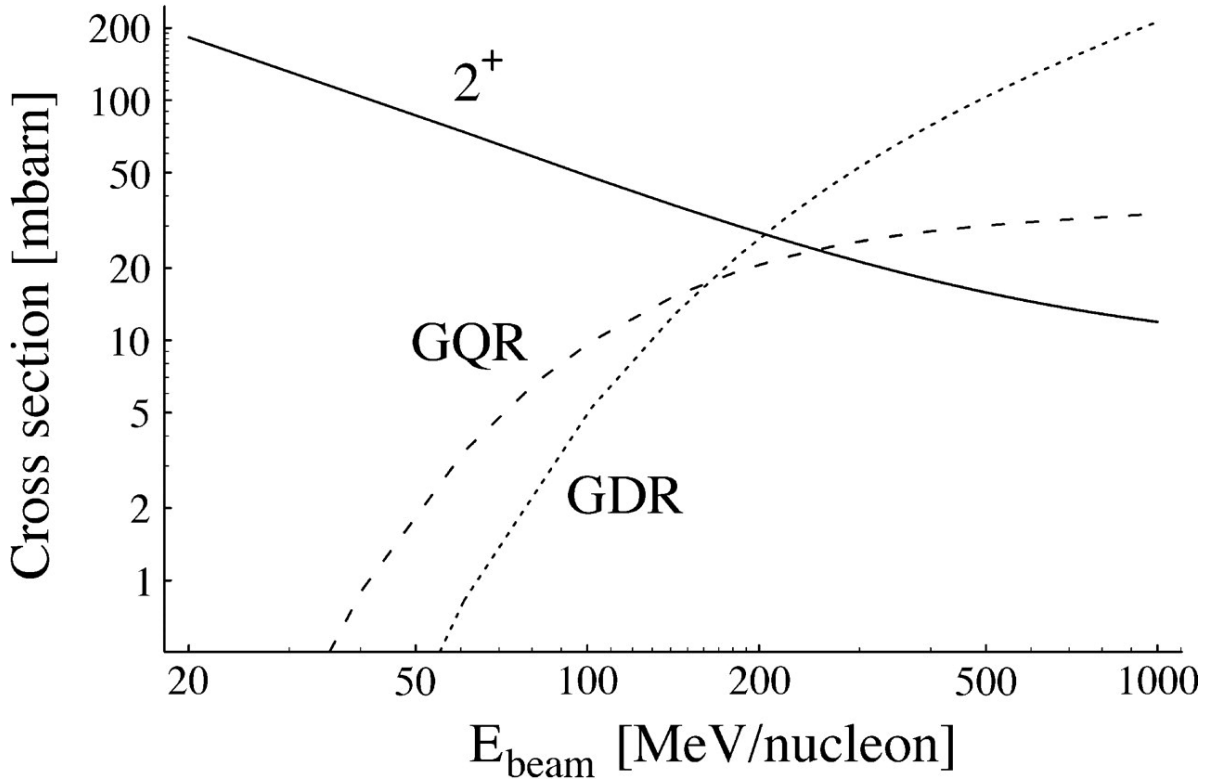




Coulomb excitation at intermediate energies

Important aspects :

1) Choice of target material
➔ High Z target for Coulomb excitation (e.g. ^{208}Pb, ^{197}Au)
Coulex of the target
➔ Low Z target for measuring the nuclear cross-section
2) Choice of target thickness
3) Choice of beam energy
4) Choice of gamma and particle detector
5) γ-rays are emitted in flight
6) Addback and angular distribution of γ-rays (that can induce up to 4% difference in efficiency)
7) Choice of O.P.
8) How do you know that you are right? Can you trust your measurement? How do you prove it?



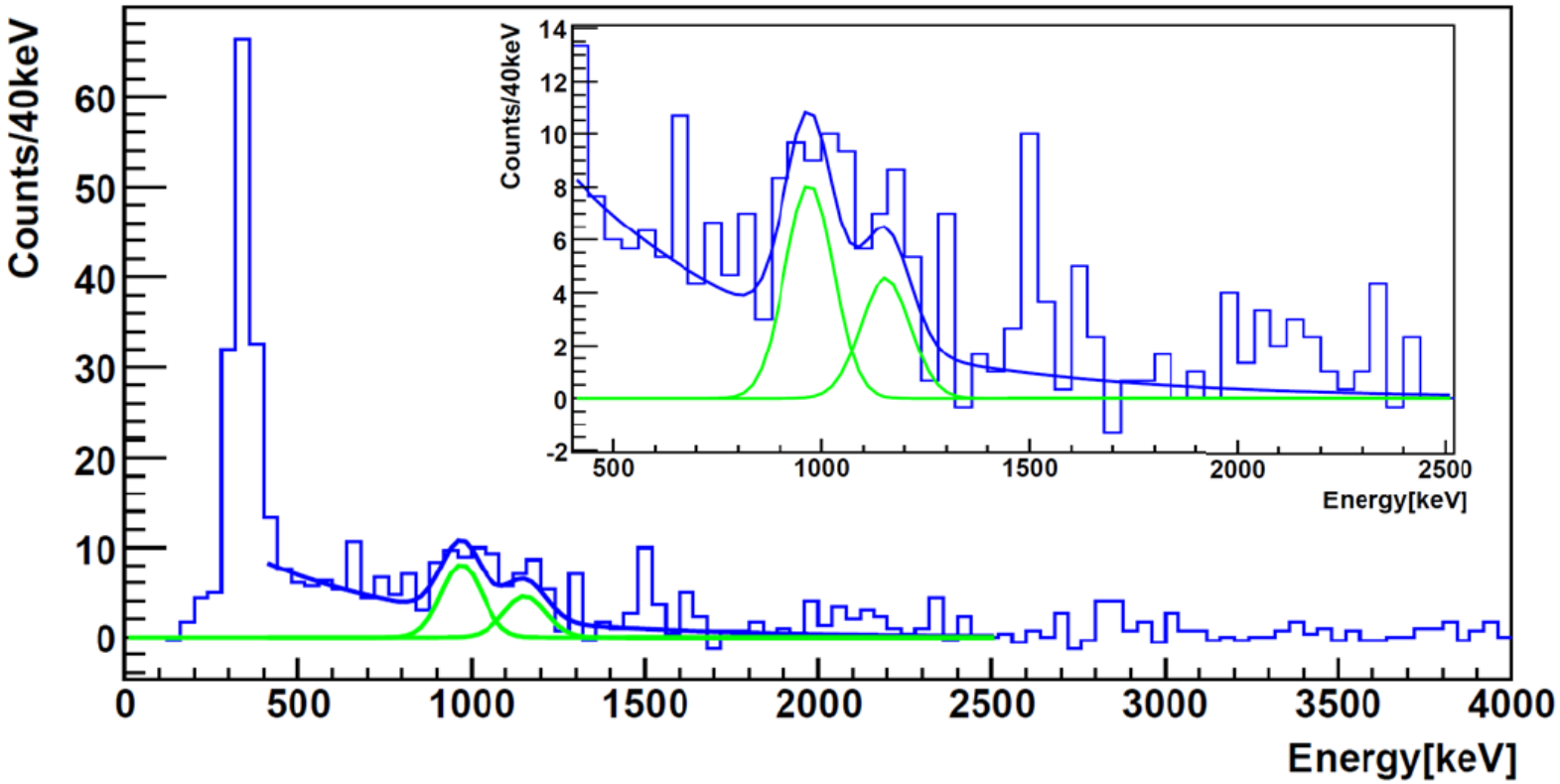
Cross sections for Coulomb excitation of the first excited state (2+), the giant dipole resonance (GDR), and the giant quadrupole resonance (GQR) for a 40S beam incident on a gold target, versus the beam energy. The calculation assumes a minimum impact parameter of 16 fm.

T. Glasmacher et all, Annu. Rev. Nucl. Part. Sci. 1998.

Coulomb excitation at intermediate energies

Important aspects :

1) Choice of target material
➔ High Z target for Coulomb excitation (e.g. ^{208}Pb, ^{197}Au)
Coulex of the target
➔ Low Z target for measuring the nuclear cross-section
2) Choice of target thickness
3) Choice of beam energy
4) Choice of gamma and particle detector
5) γ-rays are emitted in flight
6) Addback and angular distribution of γ-rays (that can induce up to 4% difference in efficiency)
7) Choice of O.P.
8) How do you know that you are right? Can you trust your measurement? How do you prove it?

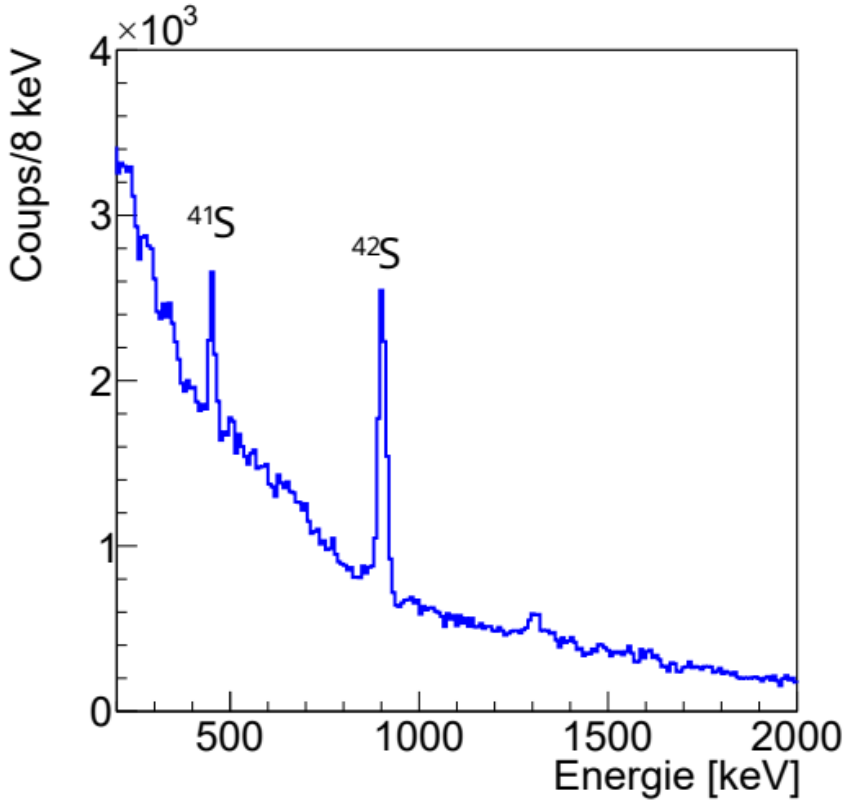


Chateau de Crystal

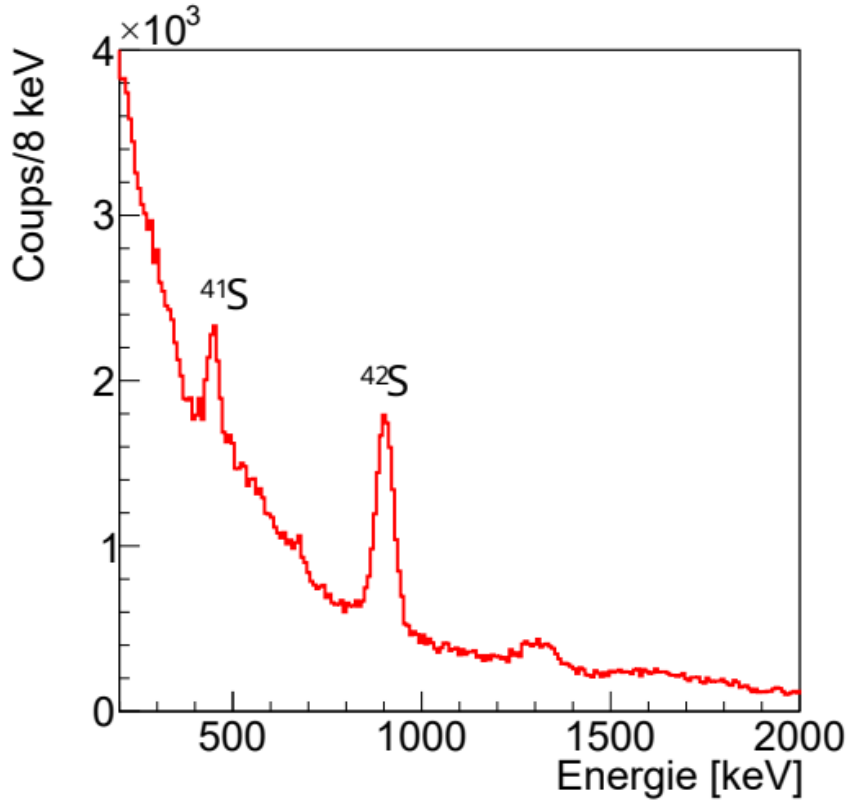
Coulomb excitation at intermediate energies

Important aspects :

1) Choice of target material
➔ High Z target for Coulomb excitation (e.g. ^{208}Pb, ^{197}Au)
Coulex of the target
➔ Low Z target for measuring the nuclear cross-section
2) Choice of target thickness
3) Choice of beam energy
4) Choice of gamma and particle detector
5) γ-rays are emitted in flight
6) Addback and angular distribution of γ-rays (that can induce up to 4% difference in efficiency)
7) Choice of O.P.
8) How do you know that you are right? Can you trust your measurement? How do you prove it?



(a) EXOGAM - Avec correction

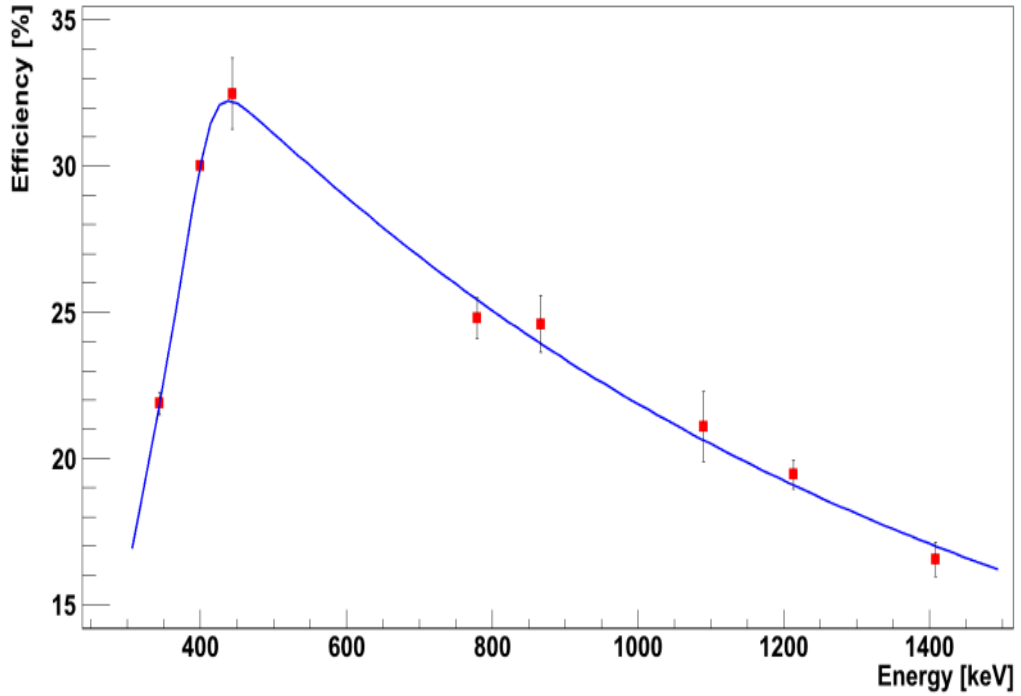


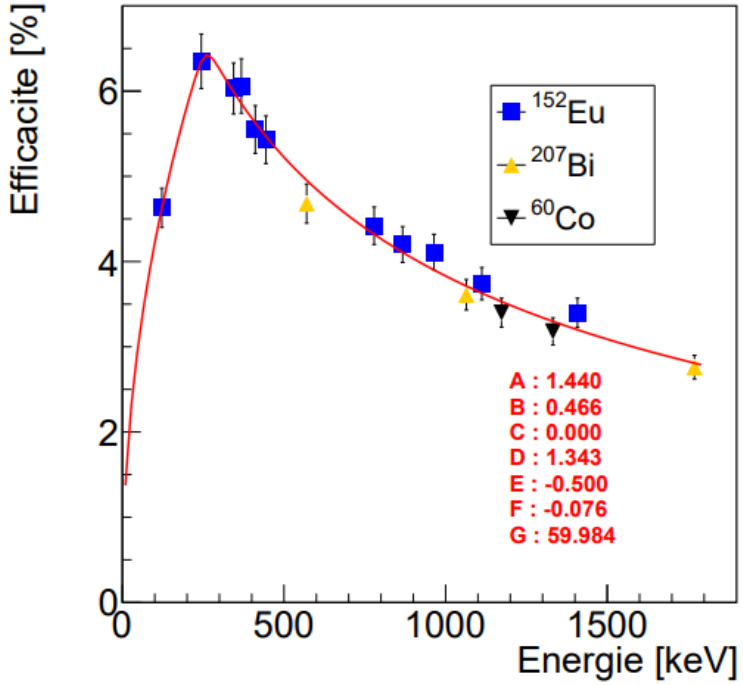
(b) PARIS - Avec correction

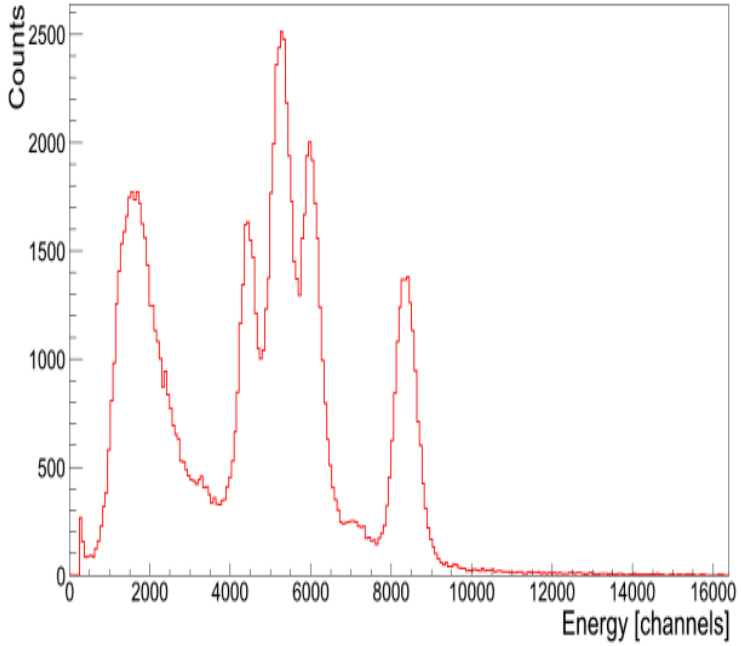
Coulomb excitation at intermediate energies

Important aspects :

1) Choice of target material
➔ High Z target for Coulomb excitation (e.g. ^{208}Pb, ^{197}Au)
Coulex of the target
➔ Low Z target for measuring the nuclear cross-section
2) Choice of target thickness
3) Choice of beam energy
4) Choice of gamma and particle detector
5) γ-rays are emitted in flight
6) Addback and angular distribution of γ-rays (that can induce up to 4% difference in efficiency)
7) Choice of O.P.
8) How do you know that you are right? Can you trust your measurement? How do you prove it?



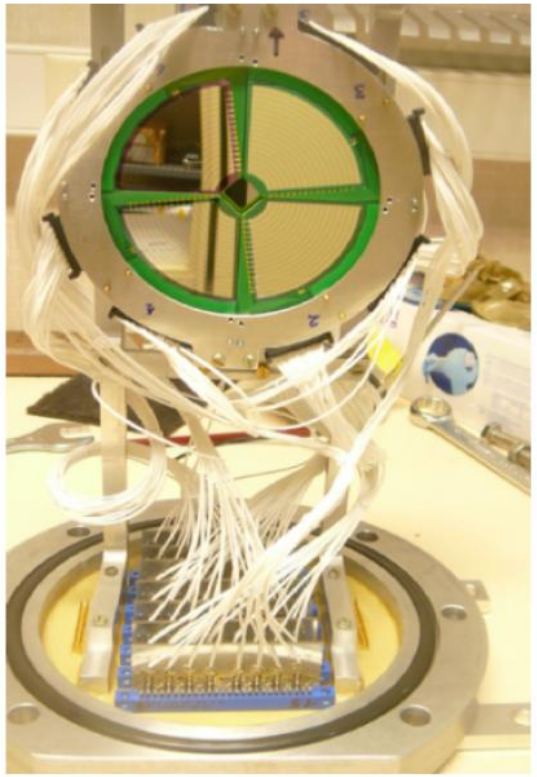


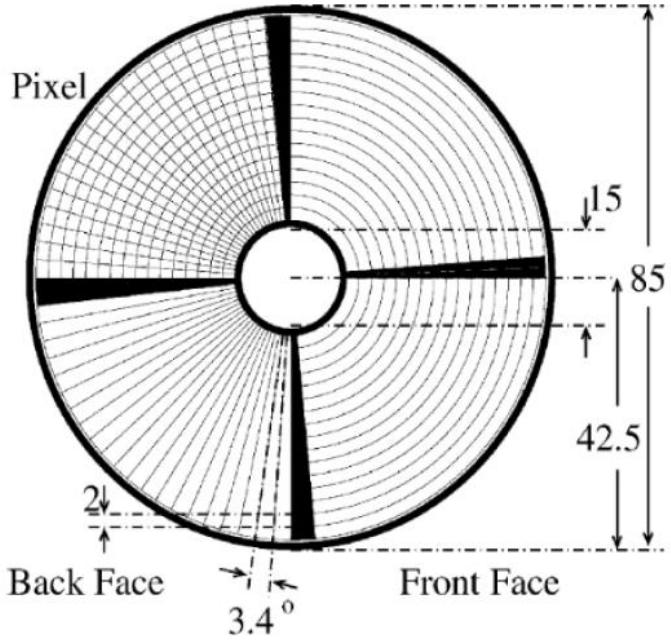


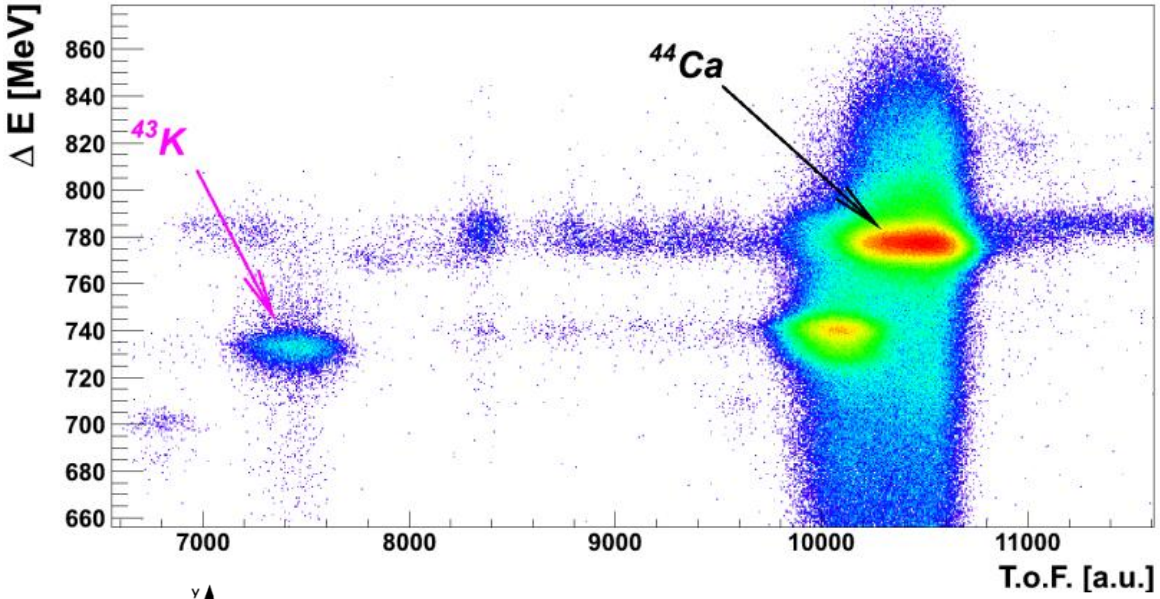
Coulomb excitation at intermediate energies

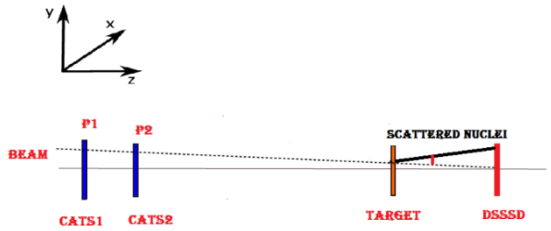
Important aspects :

1) Choice of target material
➔ High Z target for Coulomb excitation (e.g. ^{208}Pb, ^{197}Au)
Coulex of the target
➔ Low Z target for measuring the nuclear cross-section
2) Choice of target thickness
3) Choice of beam energy
4) Choice of gamma and particle detector
5) γ-rays are emitted in flight
6) Addback and angular distribution of γ-rays (that can induce up to 4% difference in efficiency)
7) Choice of O.P.
8) How do you know that you are right? Can you trust your measurement? How do you prove it?









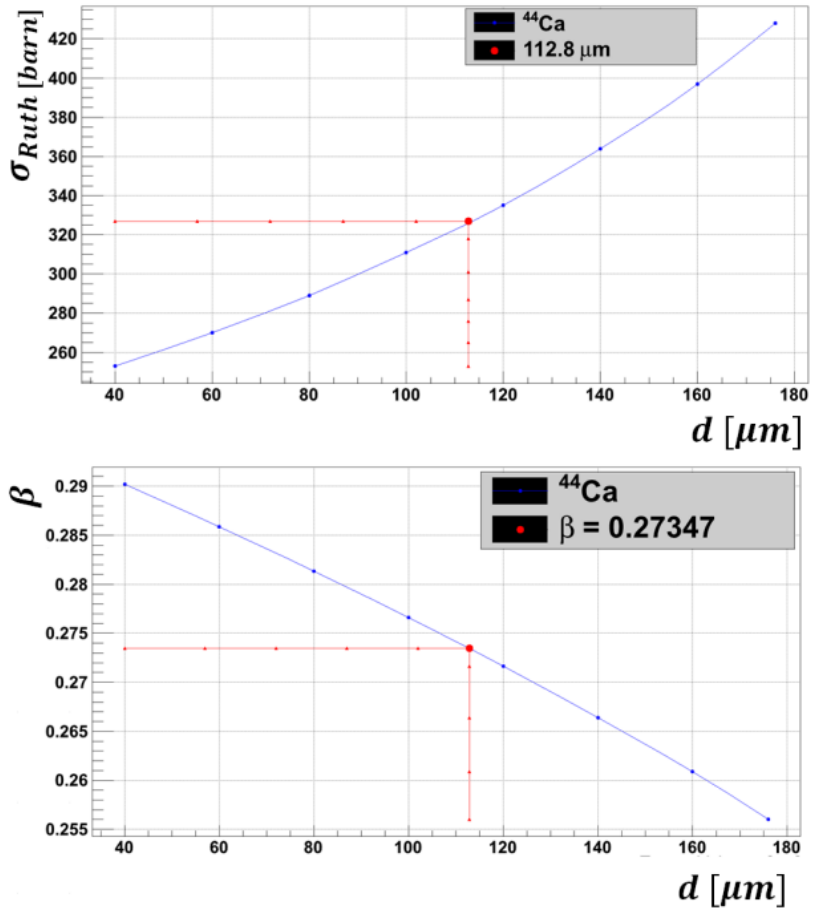
Coulomb excitation at intermediate energies

Important aspects :

1) Choice of target material
➔ High Z target for Coulomb excitation (e.g. ^{208}Pb, ^{197}Au)
Coulex of the target
➔ Low Z target for measuring the nuclear cross-section
2) Choice of target thickness
3) Choice of beam energy
4) Choice of gamma and particle detector
5) γ-rays are emitted in flight
6) Addback and angular distribution of γ-rays (that can induce up to 4% difference in efficiency)
7) Choice of O.P.
8) How do you know that you are right? Can you trust your measurement? How do you prove it?

What β ?

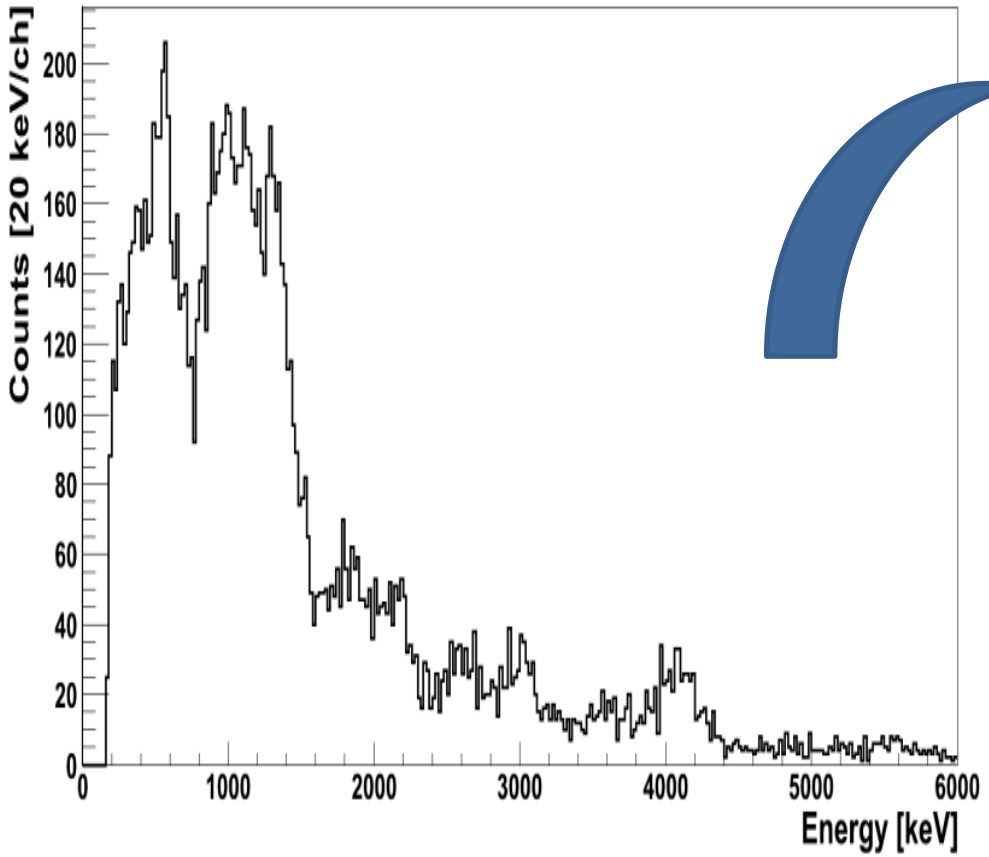
$$\theta = \frac{2Z_p Z_t e^2}{m_0 c^2 \beta^2 b\gamma},$$

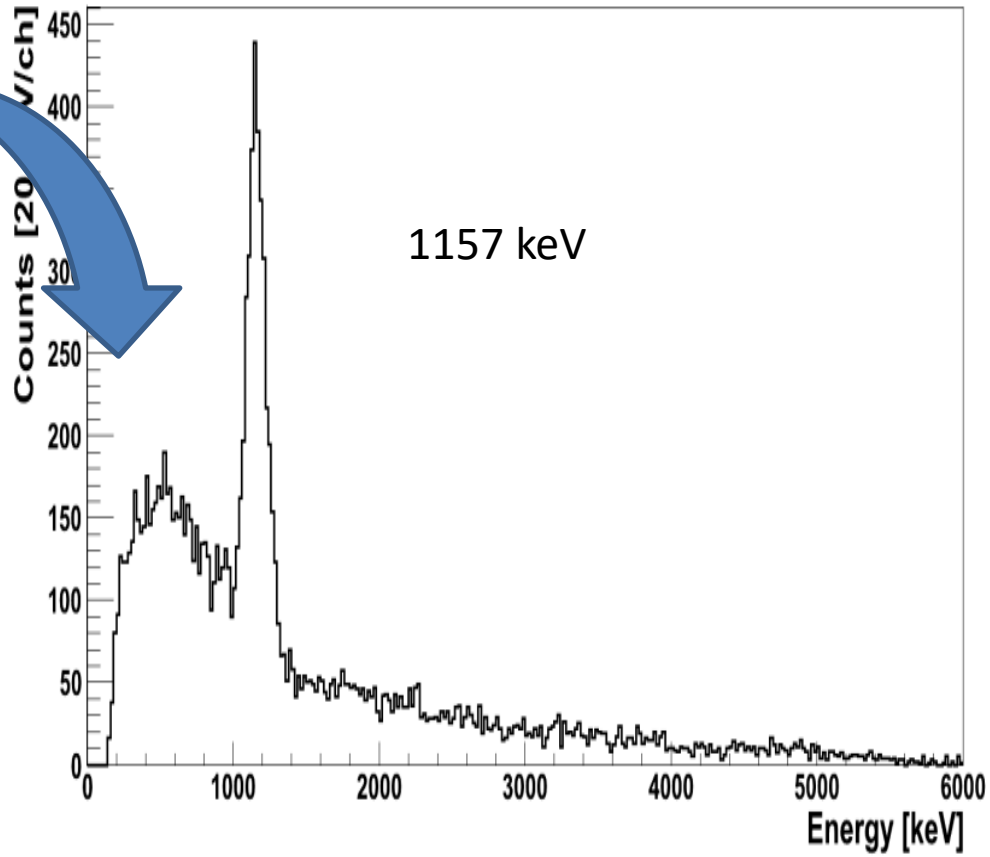


Coulomb excitation at intermediate energies

Important aspects :

1) Choice of target material
➔ High Z target for Coulomb excitation (e.g. ^{208}Pb, ^{197}Au)
Coulex of the target
➔ Low Z target for measuring the nuclear cross-section
2) Choice of target thickness
3) Choice of beam energy
4) Choice of gamma and particle detector
5) γ-rays are emitted in flight
6) Addback and angular distribution of γ-rays (that can induce up to 4% difference in efficiency)
7) Choice of O.P.
8) How do you know that you are right? Can you trust your measurement? How do you prove it?

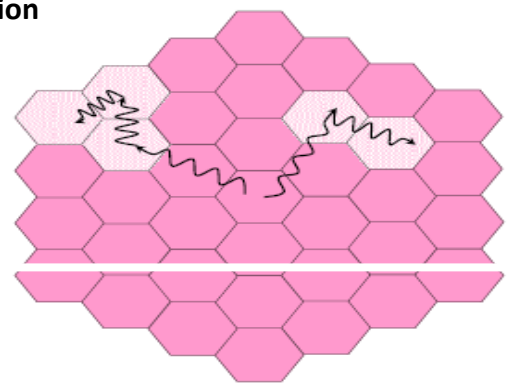




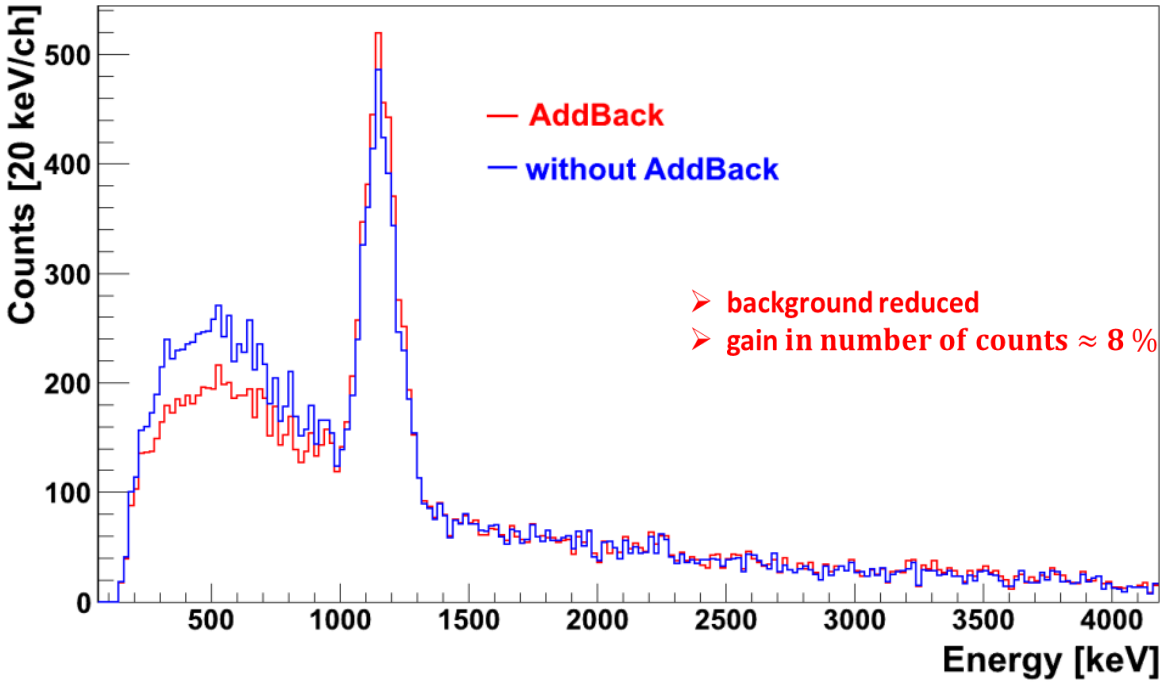
Coulomb excitation at intermediate energies

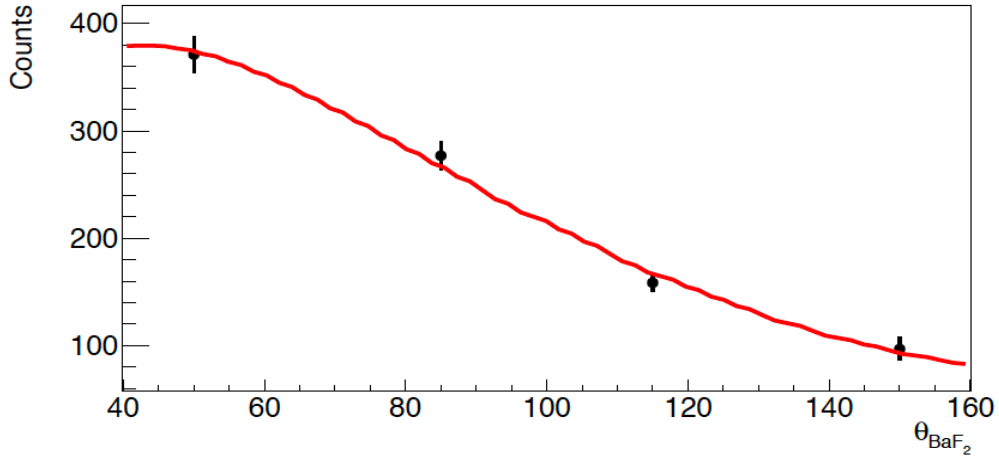
Important aspects :

1) Choice of target material
➔ High Z target for Coulomb excitation (e.g. ^{208}Pb, ^{197}Au)
Coulex of the target
➔ Low Z target for measuring the nuclear cross-section
2) Choice of target thickness
3) Choice of beam energy



4) Choice of gamma and particle detector
5) γ-rays are emitted in flight
6) Addback and angular distribution of γ-rays (that can induce up to 4% difference in efficiency)
7) Choice of O.P.
8) How do you know that you are right? Can you trust your measurement? How do you prove it?





E2 transition
Red: DWEIKO
Black: experiment

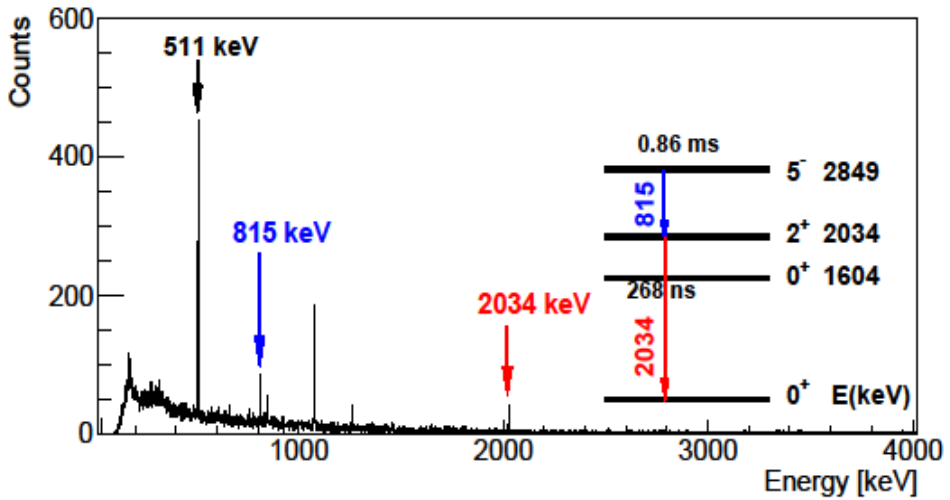
Coulomb excitation at intermediate energies

Important aspects :

1) Choice of target material
➔ High Z target for Coulomb excitation (e.g. ^{208}Pb, ^{197}Au)
Coulex of the target
➔ Low Z target for measuring the nuclear cross-section
2) Choice of target thickness
3) Choice of beam energy
4) Choice of gamma and particle detector
5) γ-rays are emitted in flight
6) Addback and angular distribution of γ-rays (that can induce up to 4% difference in efficiency)
7) Choice of O.P.
8) How do you know that you are right? Can you trust your measurement? How do you prove it?

Multistep Excitation and Isomeric Contamination

- At intermediate energies, direct population of the first 2^+ state via one-step excitation dominates.
- However, higher-lying states (e.g., 4^+, 2_2^+) may be weakly populated via multistep processes.
- These have low cross sections and are typically negligible unless explicitly studied.
- Isomeric contamination can affect B(E2) normalization:
- Isomeric states may bypass the $2^+ \rightarrow 0^+$ transition.
- Gamma intensity reduction → leads to underestimated B(E2).
- Correction requires knowledge of beam composition and lifetimes.



Coulomb excitation at intermediate energies

Important aspects :

1) Choice of target material
➔ High Z target for Coulomb excitation (e.g. ^{208}Pb, ^{197}Au)
Coulex of the target
➔ Low Z target for measuring the nuclear cross-section
2) Choice of target thickness
3) Choice of beam energy
4) Choice of gamma and particle detector
5) γ-rays are emitted in flight
6) Addback and angular distribution of γ-rays (that can induce up to 4% difference in efficiency)
7) Choice of O.P.
8) How do you know that you are right? Can you trust your measurement? How do you prove it?

Simulation Codes and Theoretical Modeling

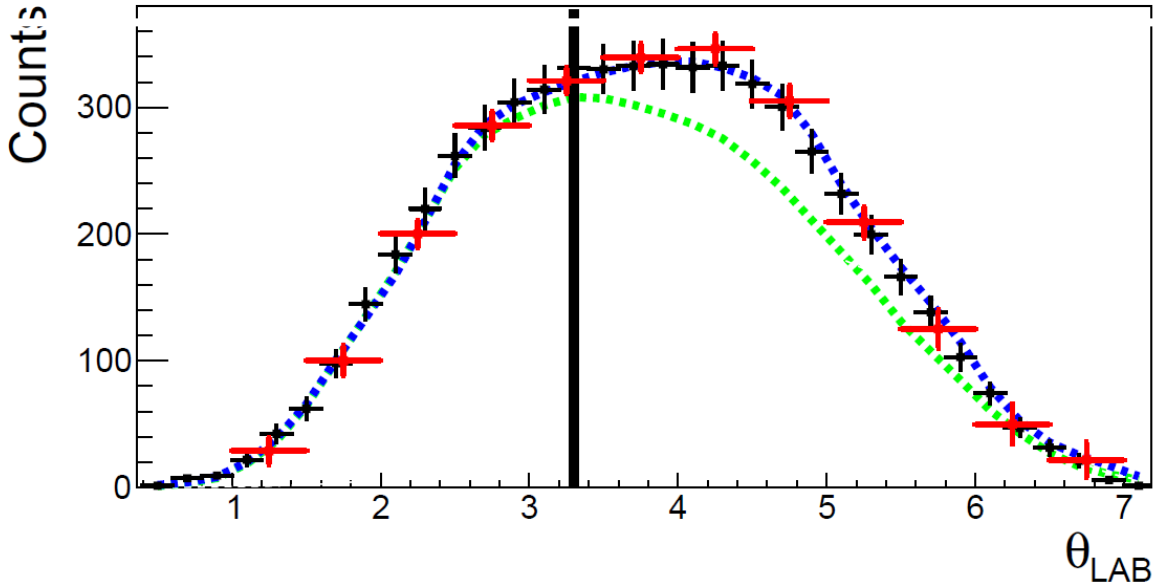
Theoretical modeling is essential to interpret angular distributions and extract B(E2) values.

Common tools:
DWEIKO: semiclassical code for Coulomb and nuclear excitation at intermediate energies.
ECIS: coupled-channels code based on optical model potentials.

Inputs required:
➔Optical model parameters (e.g., depth, radius, diffuseness of nuclear potential).
➔Nuclear deformation parameters (β_2, β_4).
➔Beam and target properties (Z, A, energy, thickness).

Output:
➔Differential cross-sections for each transition.
➔Angular distributions to be compared with experiment.

Fitting procedure:
➔Adjust model parameters (e.g., B(E2)) to match experimental distributions.
➔χ^2 minimization or visual matching used for best-fit extraction

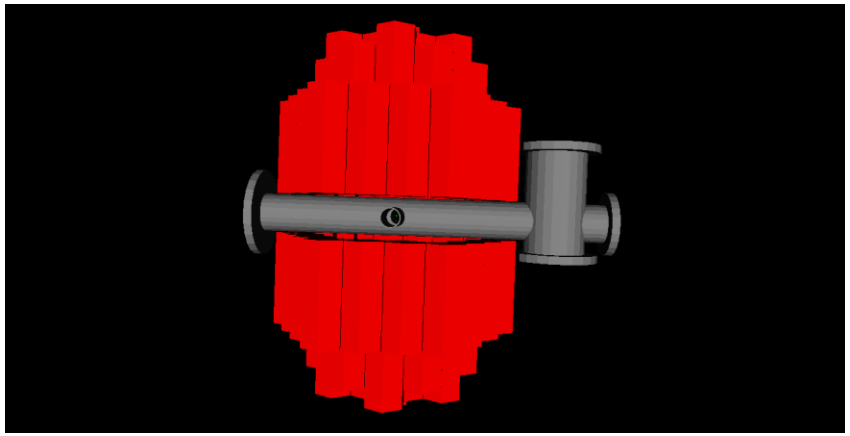


2 methods for fitting the angular distribution:
- γ ray method
- DSSSD method

Coulomb excitation at intermediate energies

Important aspects :

1) Choice of target material
➔ High Z target for Coulomb excitation (e.g. ^{208}Pb, ^{197}Au)
Coulex of the target
➔ Low Z target for measuring the nuclear cross-section
2) Choice of target thickness
3) Choice of beam energy
4) Choice of gamma and particle detector
5) γ-rays are emitted in flight
6) Addback and angular distribution of γ-rays (that can induce up to 4% difference in efficiency)
7) Choice of O.P.
8) How do you know that you are right? Can you trust your measurement? How do you prove it?



^{34}Si+^{197}Au@55 MeV/A

U_{opt} : ^{40}Ar+^{208}Pb@ 44 MeV/A ➔ σ = 19 mb
U_{opt} : ^{17}O+ ^{208}Pb @ 84MeV/A ➔ σ = 21 mb
U_{opt} : ^{86}Kr+ ^{208}Pb @ 43MeV/A ➔ σ = 15 mb
U_{opt} : ^{40}Ar+ ^{208}Pb @ 41MeV/A ➔ σ = 20 mb

Up to 28% uncertainty!

DETECTOR		Horizontal displacement (dx) $\pm 0.15\ mm$	Vertical displacement (dz) $\pm 0.15\ mm$	Vertical dist. from dipole axis (dy) $\pm 1.0\ mm$	Note
CATS1		+ 0.2	− 0.4	+ 1 345	Window center
Mask CATS		+ 0.1	0	+ 1 834	Central hole
CATS2		+ 0.5	0	+ 1 977	Window center
Target support	Mask	Reference on the manual Reproducible until $\pm 0.3\ mm$	+ 0.1	+ 2 720	Central hole
	Support1		+ 0.5		Support center
	Support2		+ 0.75		
	Support3		+ 0.9		
DSSSD		− 0.7	+ 0.3	+ 3 132	Central hole

Coulomb excitation at intermediate energies

Important aspects :

1) Choice of target material
➔ High Z target for Coulomb excitation (e.g. ^{208}Pb, ^{197}Au)
Coulex of the target
➔ Low Z target for measuring the nuclear cross-section
2) Choice of target thickness
3) Choice of beam energy
4) Choice of gamma and particle detector
5) γ-rays are emitted in flight
6) Addback and angular distribution of γ-rays (that can induce up to 4% difference in efficiency)
7) Choice of O.P.
8) How do you know that you are right? Can you trust your measurement? How do you prove it?

A well known B(E2) value from a nucleus
➔ Can be produced in the experiment
➔ B(E2) value consistent from different type of measurements
➔ Extract the B(E2) from the absolute cross-section measurement and compared with the adopted value
➔ Extra-check : relative measurement

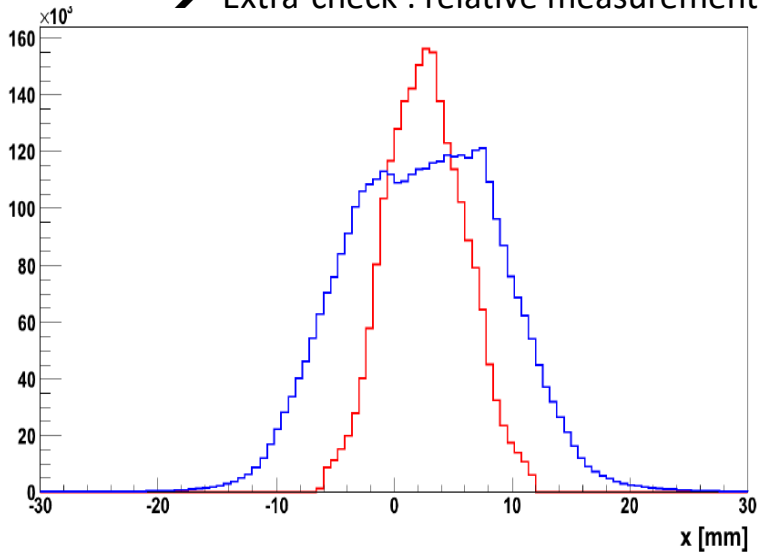


Figure 7.40: Beam profile on the target for ^{44}Ca (red) and ^{46}Ar (blue)

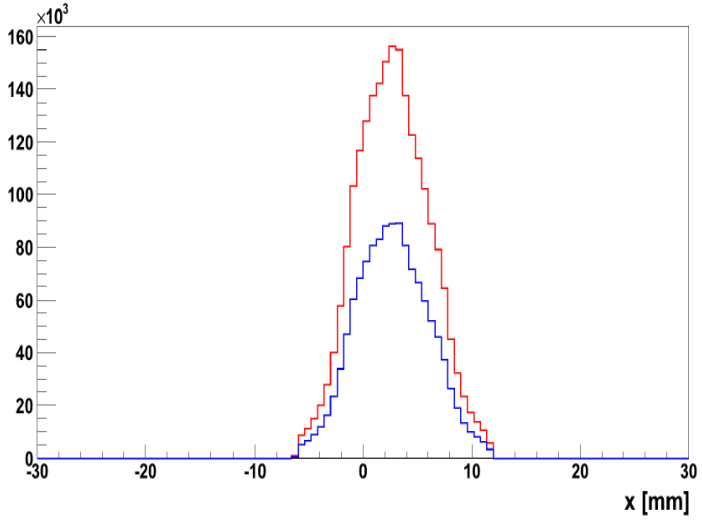


Figure 7.41: Beam profile on the target for ^{44}Ca (red) and ^{46}Ar (blue) after applying the Monte Carlo rejection method.

Coulomb excitation at intermediate energies

Selection of a “coulex” event

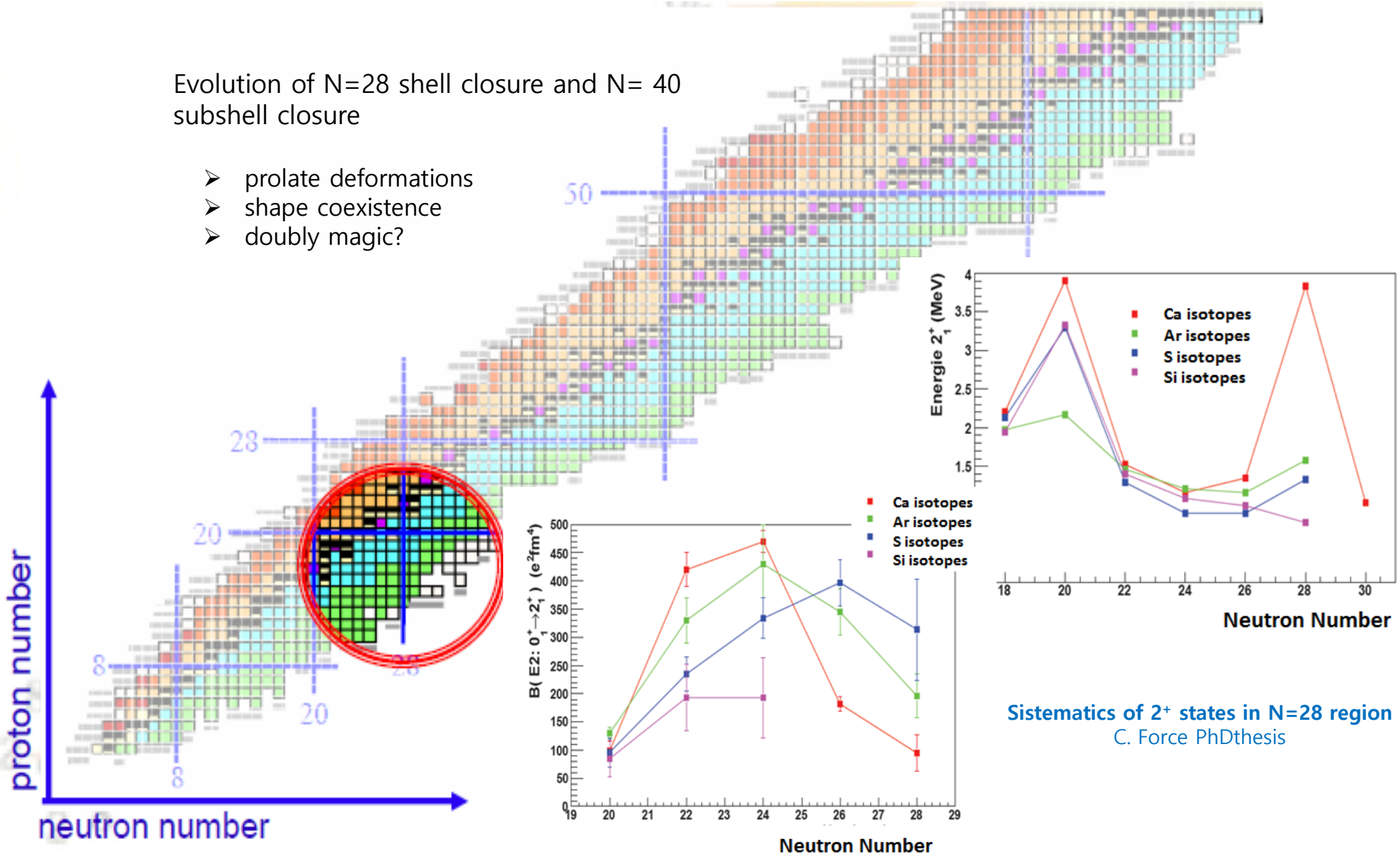
The procedure applied in the data analysis can be summarized in 6 steps, as follows:

1. selection of the fragment of interest before and after the secondary target
2. particle-γ-ray coincidence condition
3. Doppler correction of detected γ-rays.
4. requesting a narrow time gate for the gamma spectrum
5. selecting events with gamma multiplicity M_γ=1
6. limit the scattering angle of the residue projectiles to small angles (less than the grazing angle for the reaction).

From Virtual Photons to Nuclear Deformation: The Harsh Elegance of Coulomb Excitation

Evolution of N=28 shell closure and N= 40 subshell closure

- prolate deformations
- shape coexistence
- doubly magic?

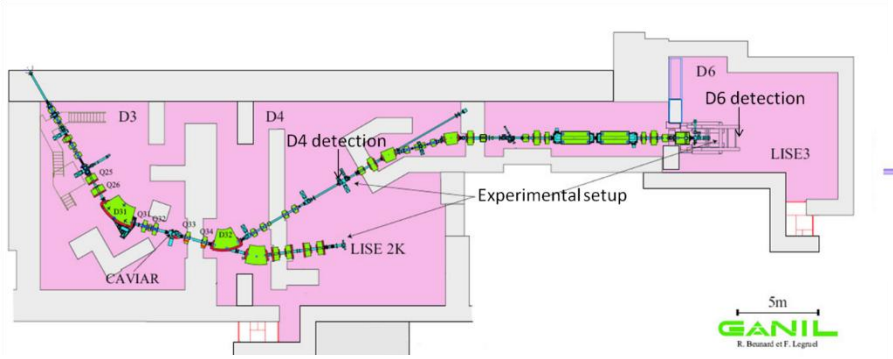


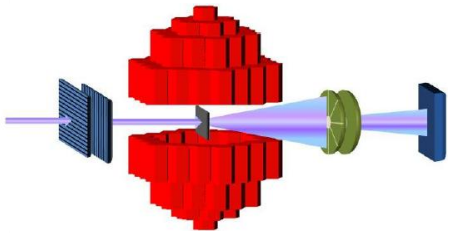
Sistematics of 2^+ states in N=28 region
C. Force PhDthesis

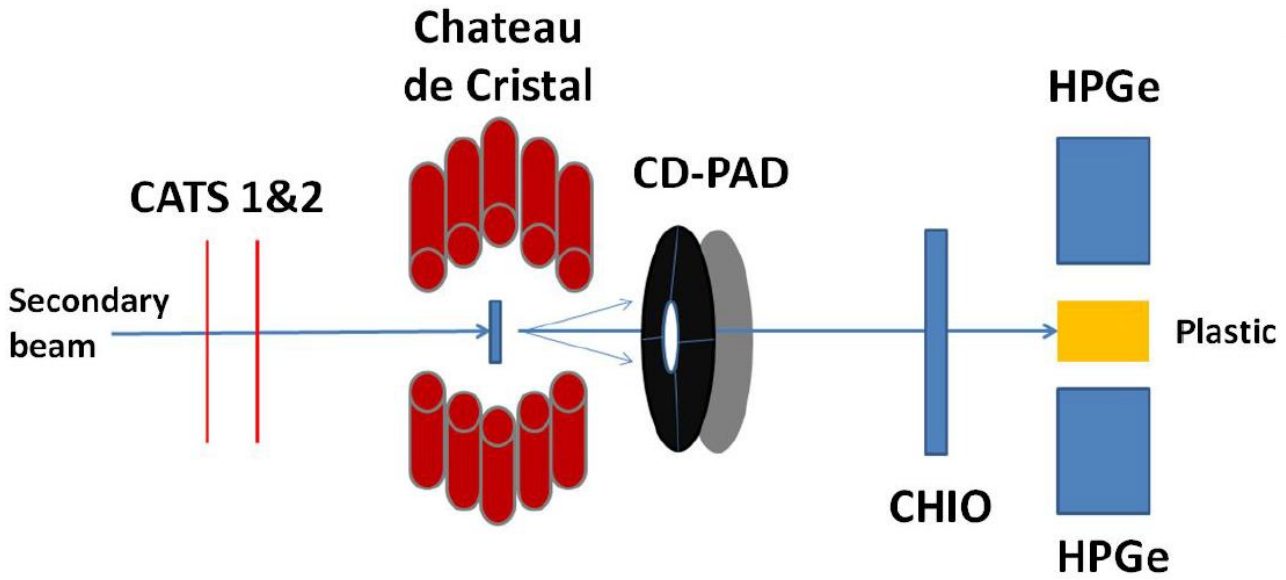
Primary beams:

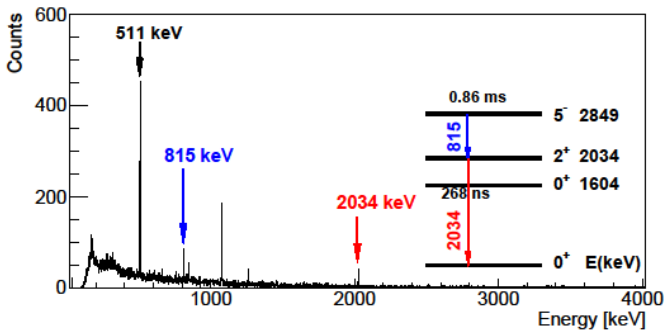
^{48}Ca@60MeV/A

^{70}Zn@60MeV/A









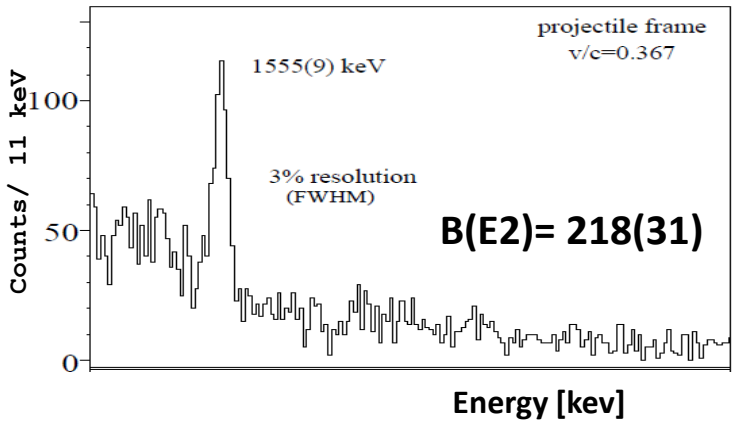
^{44}Ca on electromagnetic (Pb) @ 36.8 MeV/A
^{70}Zn on electromagnetic (Pb) @ 51.8 MeV/A
^{68}Ni on electromagnetic (Pb) and nuclear probe (C) @ 47MeV/A

^{46}Ar previous information

Coulomb excitation experiments: B(E2;0^{++})

Secondary beam	^{38}S	^{40}S	^{42}S	^{44}Ar	^{46}Ar
Energy (MeV/nucleon)	39.2	39.5	40.6	33.5	35.2
Beam purity	0.99	0.65	0.55	0.99	0.99
Typical intensity on target (s^{-1})	50 000	17 000	1800	50 000	27 000
Energy loss in target (MeV/nucleon)	9.1	8.4	7.9	5.1	4.9
Energy of first excited state (keV)	1286(19)	891(13)	890(15)	1144(17)	1554(26)
$\sigma(E2;0^+_{g.s.} \rightarrow 2^+_1, \theta_{lab} \leq 4.1°)$ (mbarn)	59(7)	94(9)	128(19)	81(9)	53(10)
$B(E2;0^+_{g.s.} \rightarrow 2^+_1)$, ($e^2$ fm^4)	235(30)	334(36)	397(63)	345(41)	196(39)
$\lvert\beta_2\rvert$	0.246(16)	0.284(16)	0.300(24)	0.241(14)	0.176(17)

H. Scheit et al., Phys.Rev.Lett 77 (1996)

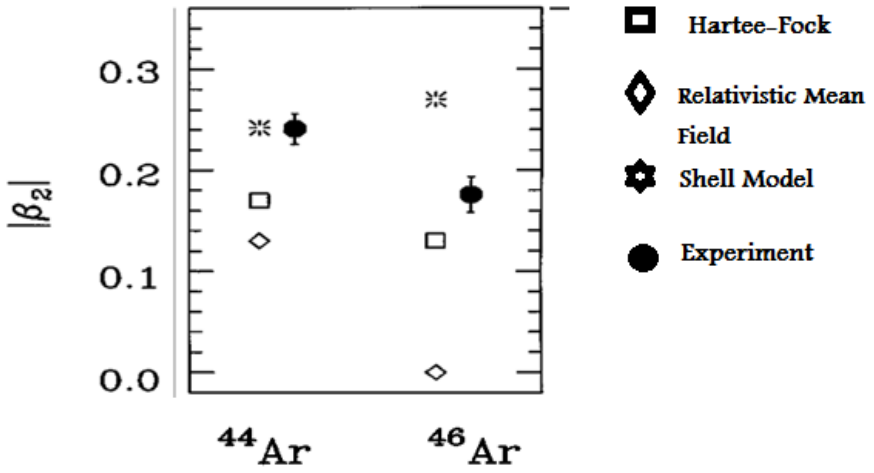


Gade et al., Phys. Rev. C 74 (2006)

Half-time measurement: B(E2;2^+0^+)

Isotope	E_γ (keV)	$J^\pi_i \rightarrow J^\pi_f$	τ (ps)	$B(E2)$ (e^2fm^4)
^{44}Ar	1158	$2^+ \rightarrow 0^+$	5.9(2.0)	67^{+44}_{-17}
	1588	$4^+ \rightarrow 2^+$	$3.9^{+3.6}_{-2.9}$	21^{+60}_{-10}
	693	$6^+ \rightarrow 4^+$	>40	<128
^{46}Ar	1552	$2^+ \rightarrow 0^+$	$0.8^{+0.3}_{-0.4}$	114^{+67}_{-32}

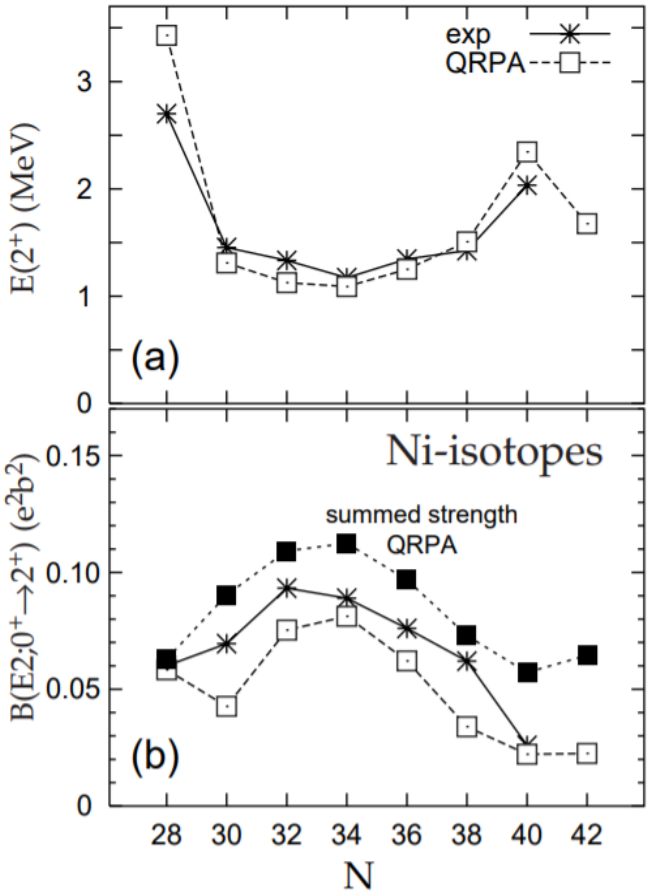
D. Mengoni et al., Phys.Rev.C 82 (2010)



Doubly magic ^{68}Ni ?

B(E2:0_1^+->2_1^+) = 280(60) e^2fm^4

O. Sorlin et al., Phys. Rev. Lett. 88, 092501 (2002).



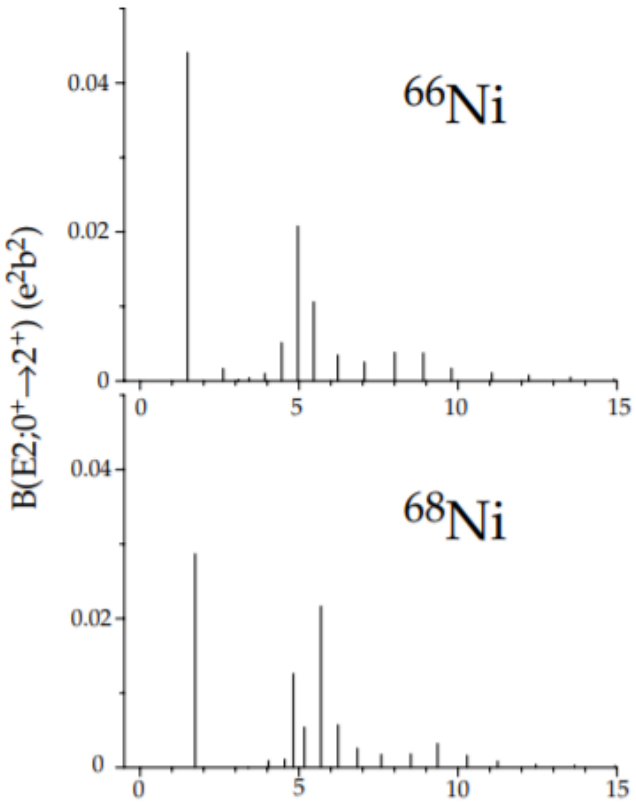
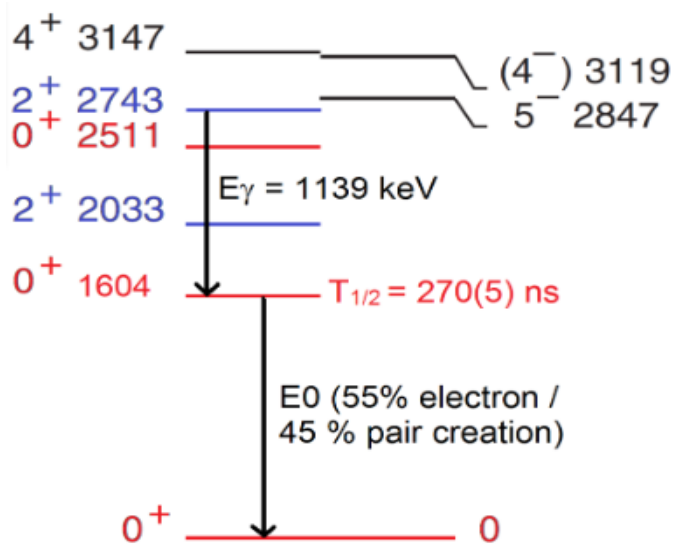


FIG. 4. Distribution of the $B(E2;0^+_{g.s.}\rightarrow 2^+_f)$ strength in ^{66,68}Ni calculated in the diagonalization shell model.

K. Langanke et al., Phys. Rev. C 67, 044314 (2003).

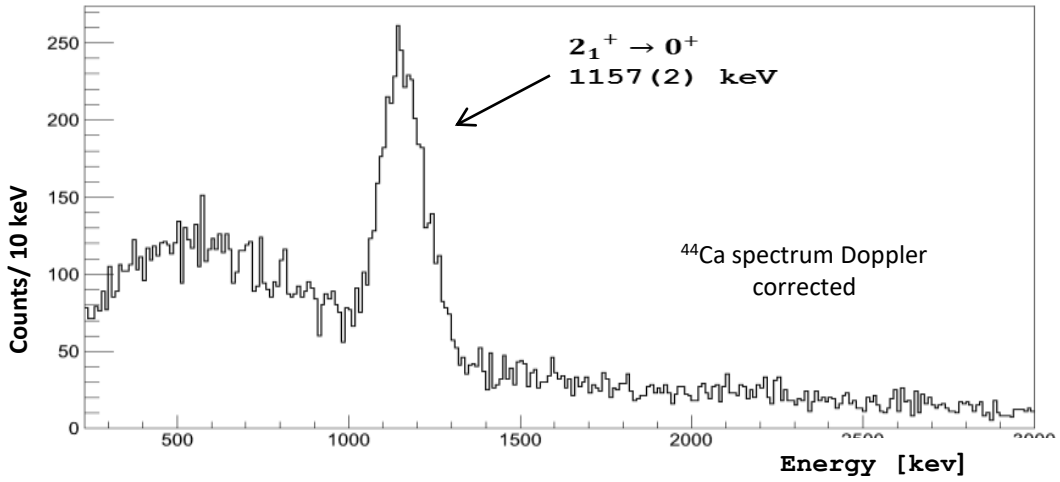


➔Most of the calculated strength resides at excitation energies around 5–6 MeV.

➔the transition to the first 2_1 state exhausts only the smaller fraction of the total shell-model B(E2) strength, calculated to be ~ 900 e^2fm^4

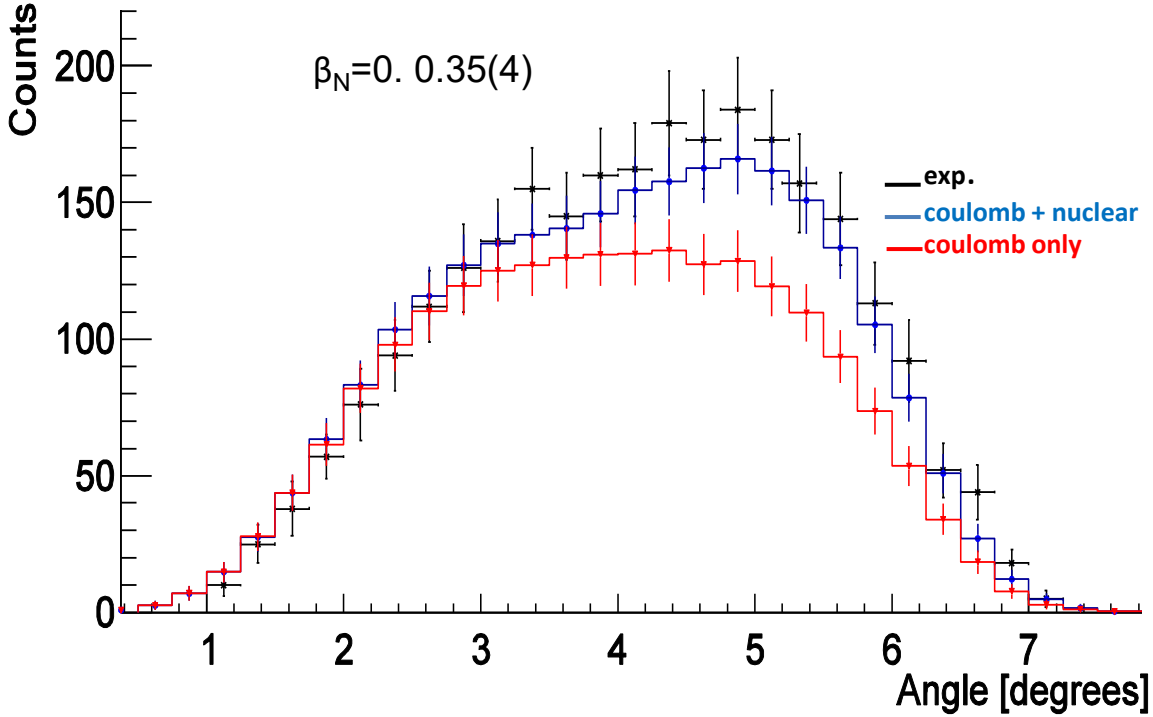
^{44}Ca

$\theta_{safe} = 4^0$



β_C=0.253(5)

β_N=0. 0.35(4)



Absolute cross section measurement

$B(E2) \uparrow = 473(20) e^2 fm^4$

D. Cline et al., N. Phys. A 204, 1973. 574

Best fit for safe zone : B(E2) = 475 (42) e²fm⁴

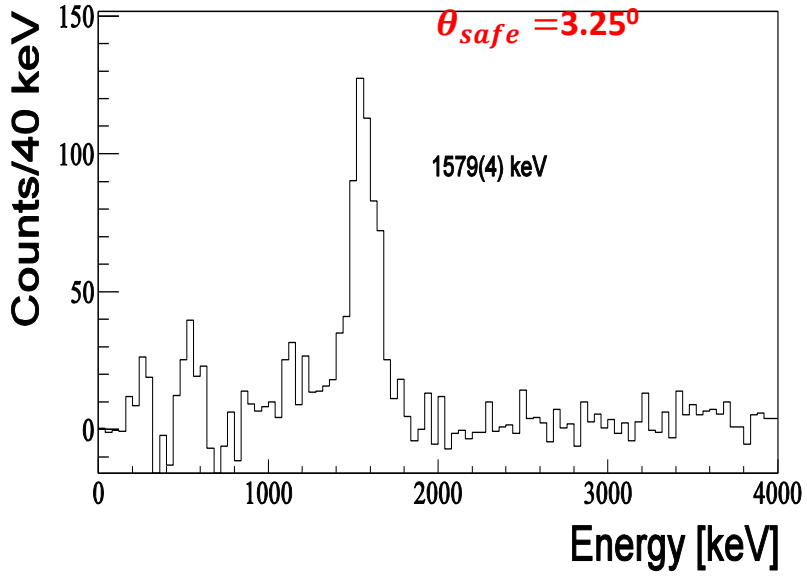
Adopted value in literature : **B(E2) = 473 (20) e²fm⁴**

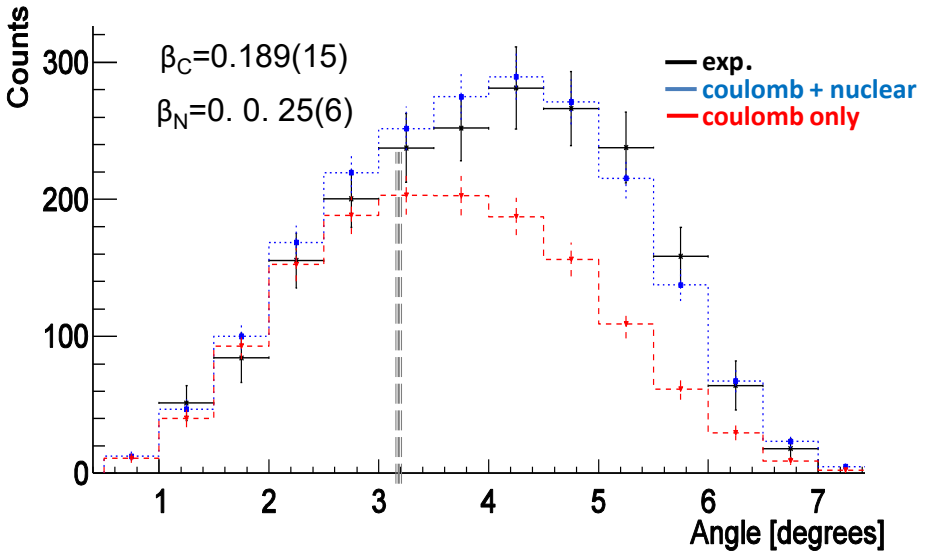
Weighted average value
from *(e,e'), Coulex, DSAM etc.:* **B(E2) = 495(35) e²fm⁴**

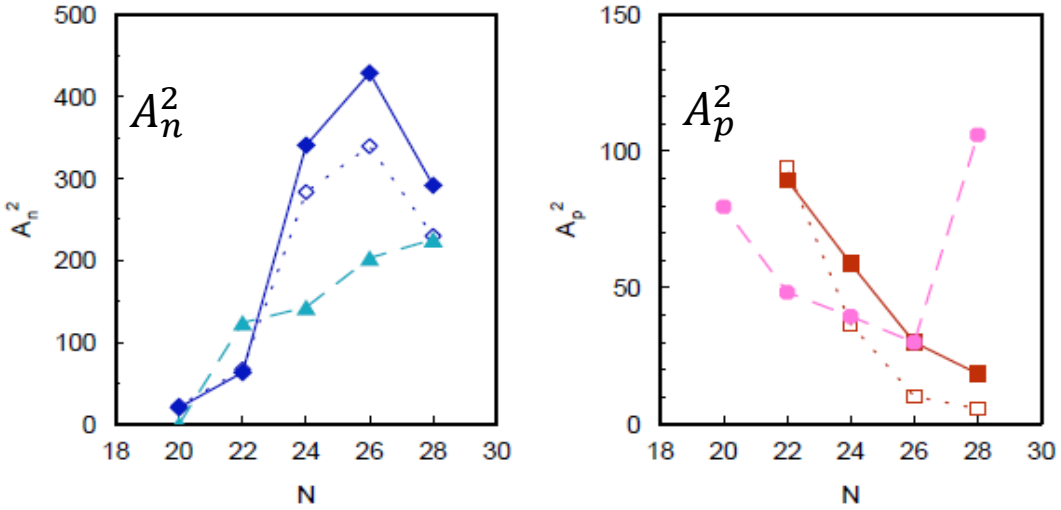
Very good agreement between the measured value of the B(E2) in this experiment and the adopted value from literature.

^{46}Ar

Extraction of B(E2:0_1^+->2_1^+) in^{46}Ar from absolute cross section measurement and relative to the known B(E2) in ^{44}Ca







Comparison of the square of the quadrupole matrix elements (given in e^2fm^4) deduced for protons and neutrons using the standard $\delta n = \delta p = 0.5$ polarization charges (solid line) and the $\delta n = 0.8$, $\delta p = 0.2$ polarization charges proposed by Riley *et al.* (dotted line) with those calculated.

Best fit for safe zone : B(E2) = 225(29) e^2fm^4

Relative to ^{44}Ca: B(E2) = $234(19)\ e^2fm^4$

In agreement with previous Coulomb excitation measurements and in contradiction with the value obtained from lifetime measurements and SM calculation.

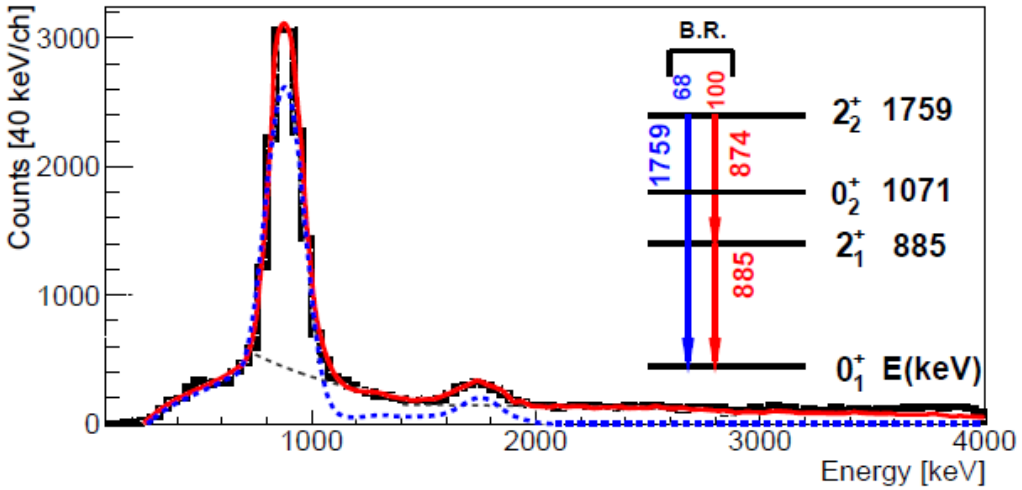
Phys. Rev. C 93, 044333 (2016)
***S. Calinescu**, L. Caceres, S Grevy, O. Sorlin et al.*

^{70}Zn data analysis

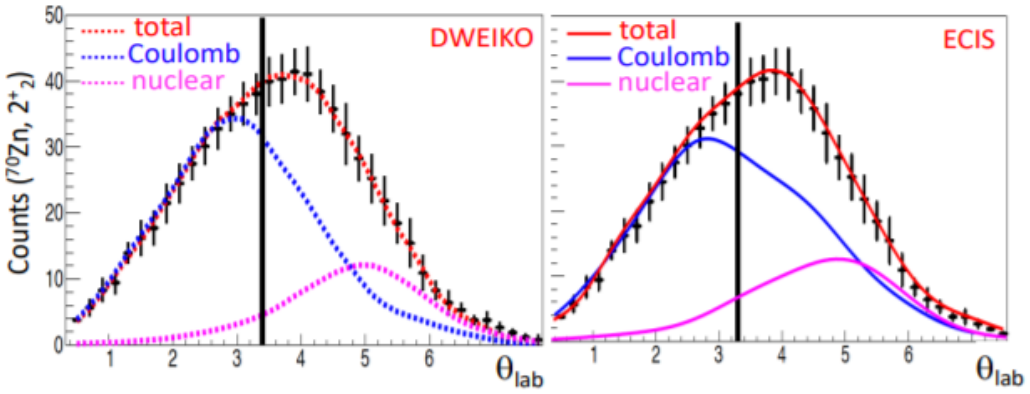
TABLE I. $B(E2; 0^+_{g.s.} \rightarrow 2^+_1)$ values (in units of e^2fm^4) in ^{70}Zn obtained from different experiments, except the last column which gives an evaluated value, based on measured ones..

	Stelson [23]	Singh [24]	Neuhausen [19]	Sorlin [16]	Kenn [25]	Celikovic [26]	Pritychenko [18]
B(E2)	1600 (140)	2350(250)	2050(190)	1640 (280)	1650 (190)	1515 (125)	1559 (80)

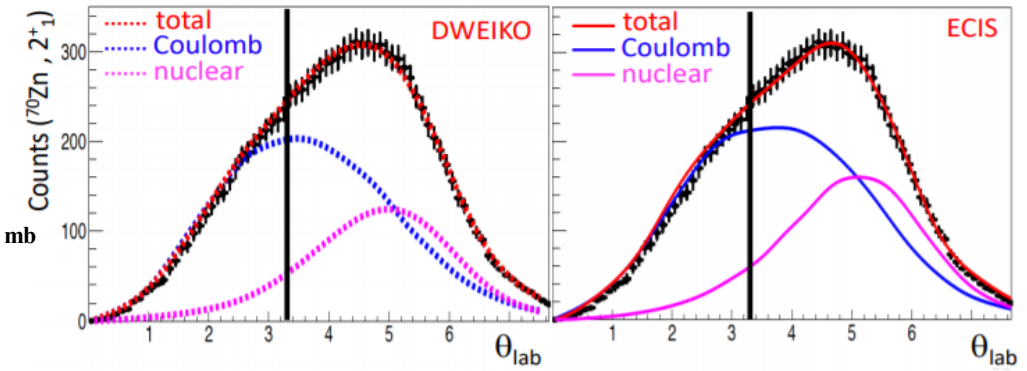
$\theta_{safe} = 3.3^0$
$\theta_{grazing} = 5^0$



$\sigma(0 \rightarrow 2^+_2) = 7.8(9)$ mb
$\sigma(2^+_1 \rightarrow 2^+_2) = 0.7$ mb



$\sigma(0 \rightarrow 2^+_1) = 228(20)$ mb



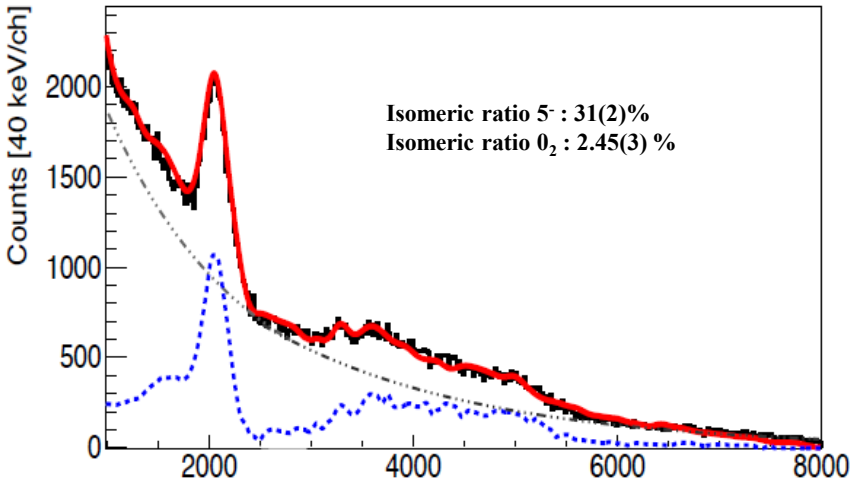
DWEIKO :
2^+_2: $\beta_N = 0.054(3), \beta_C = 0.043(3)$ ➔B(E2) = 62(7) e^2fm^4
2^+_1: $\beta_N = 0.288, \beta_C = 0.215(8)$ ➔B(E2)=1419 (120) e^2fm^4.

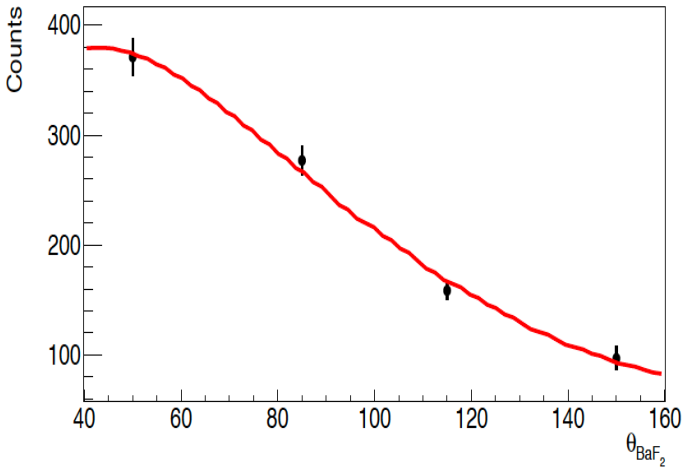
ECIS :
2^+_2: $\beta_N = 0.049(3)$, $\beta_C = 0.042(3)$ ➔B(E2)= 55(6) e^2fm^4
2^+_1 :$\beta_N = 0.241$, $\beta_C = 0.217(9)$ ➔ B(E2)=1447(127) e^2fm^4

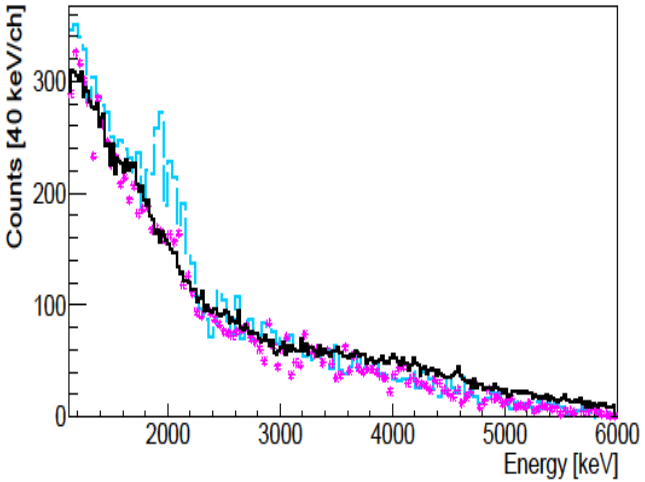
Adopted B(E2) for 2^+_2 : 50(13) e^2fm^4 from (e,e`)

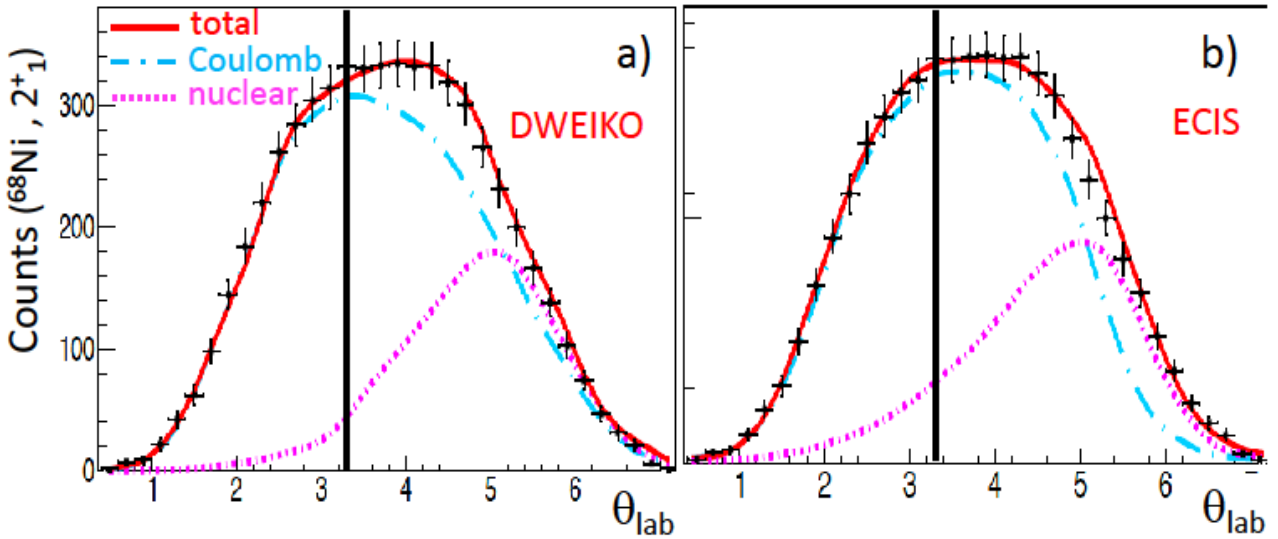
^{68}Ni data analysis

θ_{safe} =3.4^0









$\sigma(0 \rightarrow 2^+_1)$ = 55(6) mb

DWEIKO :

2^+_1: $\beta_N = 0.102(8)$,

$\beta_C = 0.1065(6)$ ➔ **B(E2) = 292(37) e^{2}fm^4**

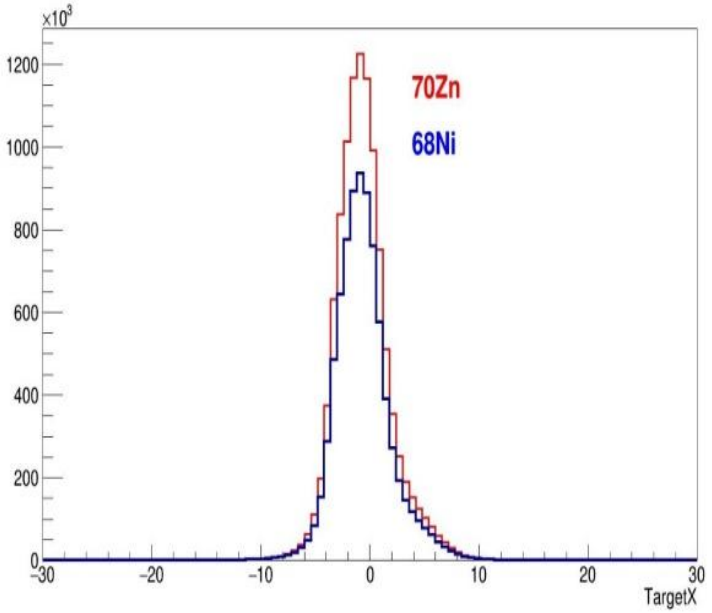
ECIS :

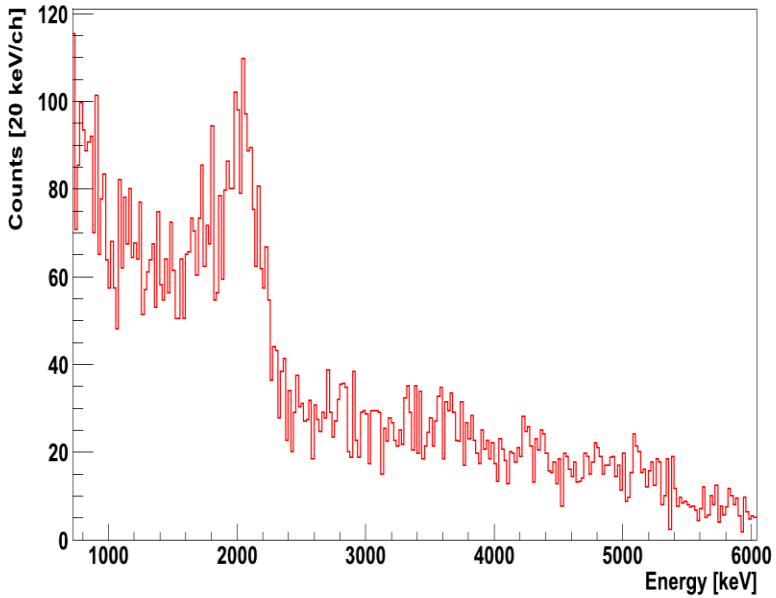
2^+_1: $\beta_N = 0.99(7)$,

$\beta_C = 0.110(7)$) ➔ **B(E2) = 312(40) e^{2}fm^4**

^{68}Ni data analysis

Relative measurement





DWEIKO :
B(E2) = 292(37) e^2fm^4

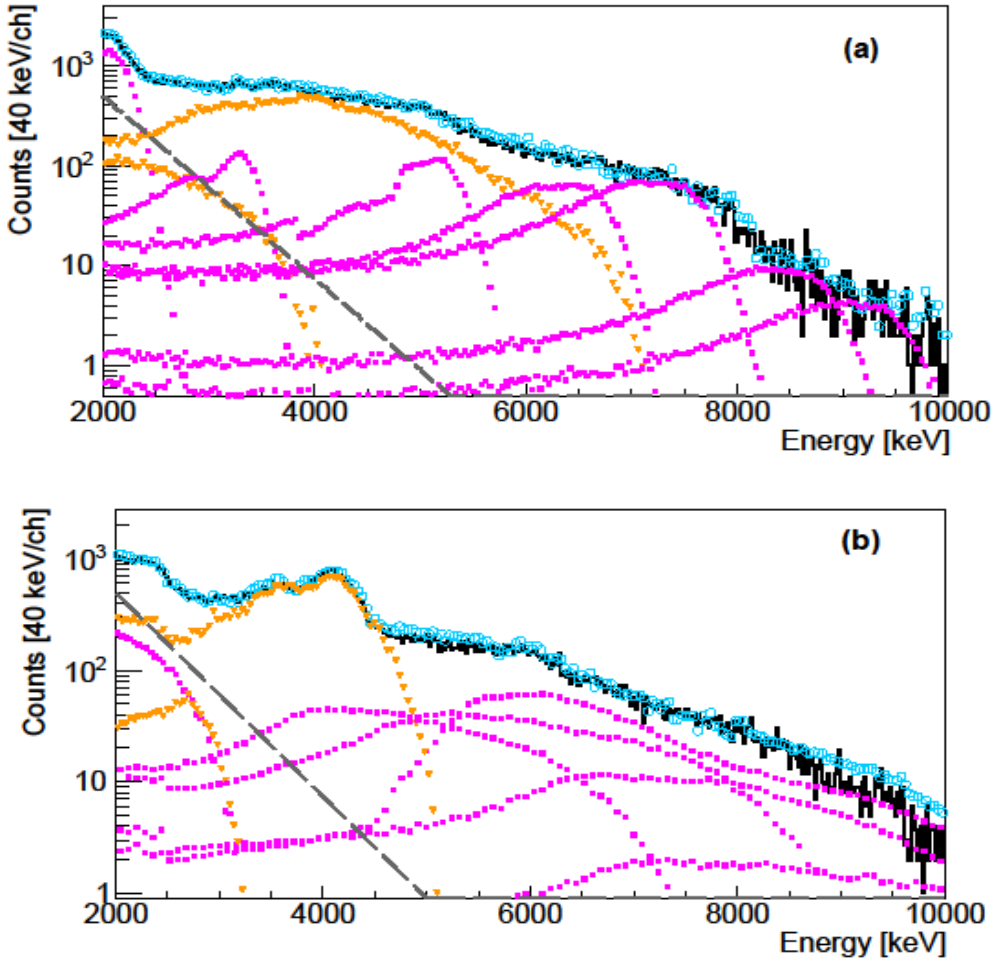
ECIS :
B(E2) = 312(40) e^2fm^4

Relative to 70Zn :
B(E2) = 305(35) e^2fm^4

TABLE II. Values β_C, β_N, $B(E2; 0^+_{g.s.} \rightarrow 2+)$ (in e^2fm^4) and the maximum 'safe' scattering angle obtained in this measurement with the DWEIKO and ECIS codes.

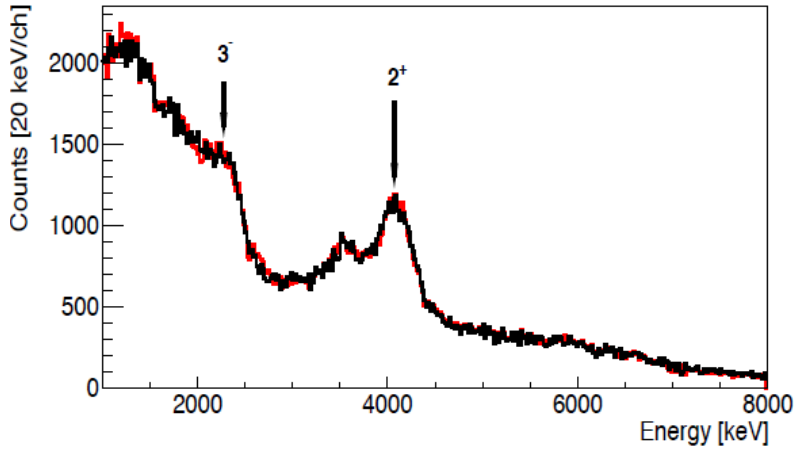
Nucleus	J^π	θ^{max}_{lab}	DWEIKO			ECIS			Adopted
			β_C	β_N	B(E2)	β_C	β_N	B(E2)	B(E2)
^{70}Zn	2^+_1	3.3°	0.215(8)	0.288(12)	1419(120)	0.217(9)	0.241(8)	1447(127)	1432(125)
^{70}Zn	2^+_2	3.3°	0.045(3)	0.054(3)	62(7)	0.042(2)	0.049(3)	55(6)	59(7)
^{68}Ni	2^+_1	3.4°	0.1065(6)	0.102(8)	292(36)	0.110(7)	0.099(7)	312(40)	300(40)

2^+_1 in ^{208}Pb : B(E2) = 3030(429) e^2fm^4 , σ = 49(7) mb
Adopted value : B(E2) = 3010(160)) e^2fm^4



S.Calinescu, et al.,Phys.Rev. C 104, 034318 (2021)

➔ summed E2 strength of only about 150 e2fm4 has been found experimentally at high excitation energy, likely due to proton excitations across the Z = 28 gap. The experimental distribution of this high-energy E2 excitation agrees with shell-model calculations, but its strength is about two times weaker.



E [MeV]	B(E2) [e^2fm^4]
3.3	15(2)
5.5	110(15)
6.3	42(5)
7.5	16(2)
8.7	?
9.3	?

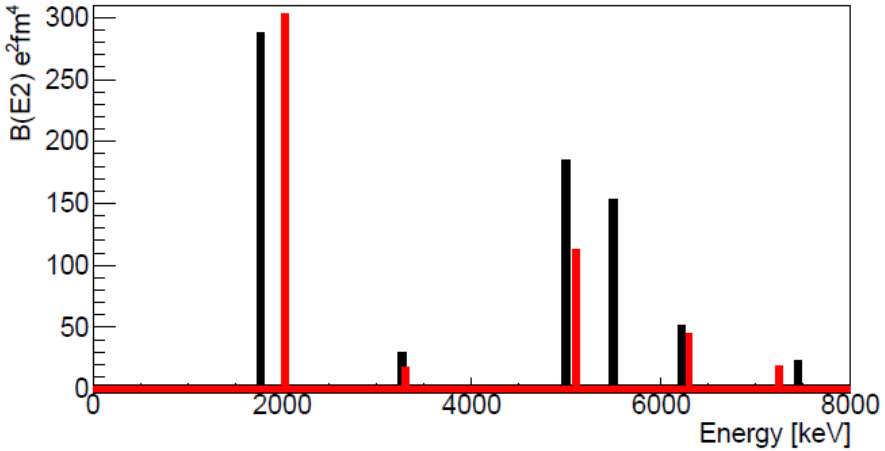


FIG. 11. Comparison between the calculated (black) and experimental (red) $B(E2; 0^+_{g.s.} \rightarrow 2^+)$ strength distribution in ^{68}Ni, up to S_n=7.79 MeV (see text for explanation).

About the outreach session …

What social media ?!

And as for ChatGPT, when used as an extension of human brain, not a replacement: major win!

Te rog da, generează o imagine realistă cu o Naja siamensis într-un terariu

Imagen creada

Ce ai făcut tu, este o Naja kaouthia care este o specie nescuipătoare și nu are culorile Naja siamensis... Uite, îți atașez o poză cu Naja siamensis. Te rog, generează o imagine care să fie în concordanță cu realitatea biologică.

Imagen creada

Greșit din nou. Ai făcut Naja naja. Eu vreau Naja siamensis.

Imagen creada

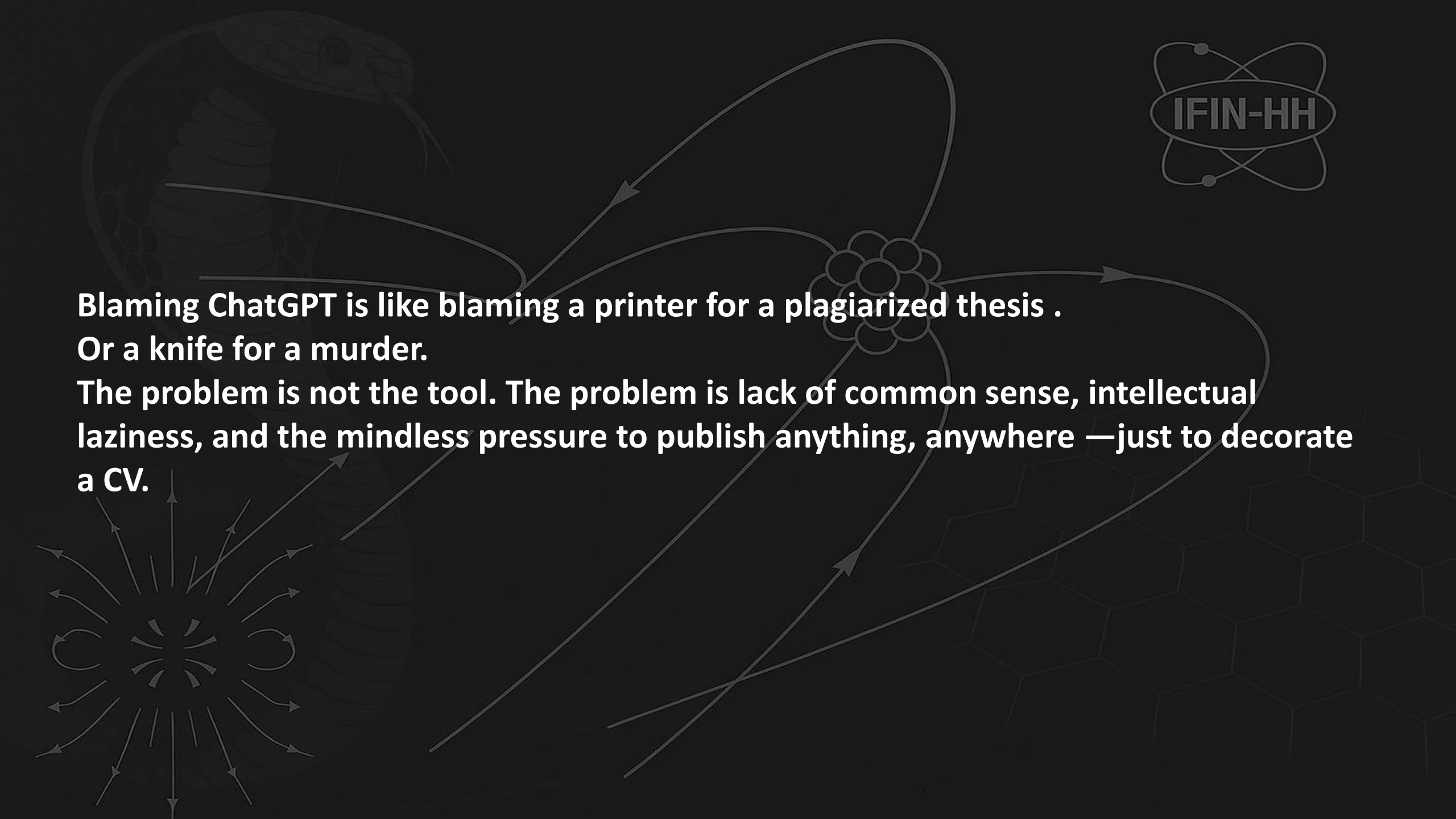
And if we're speaking about the REAL threats to science...

➔ **absence of authentic communication.**
➔ **illusion - that research is smooth, elegant, efficient.**
➔ **presenting results as if they emerged fully formed, effortlessly…But about those sleepless nights full of frustration?**
➔ **how much SOUL?**
➔ **no one speaks about failure.**

AND THERE'S MORE…

Packing twenty talks into a single session and giving each speaker 15 minutes - as if a year or two of work can be reduced to a bullet point summary - is not a celebration of scientific clarity. It's institutionalized superficiality.

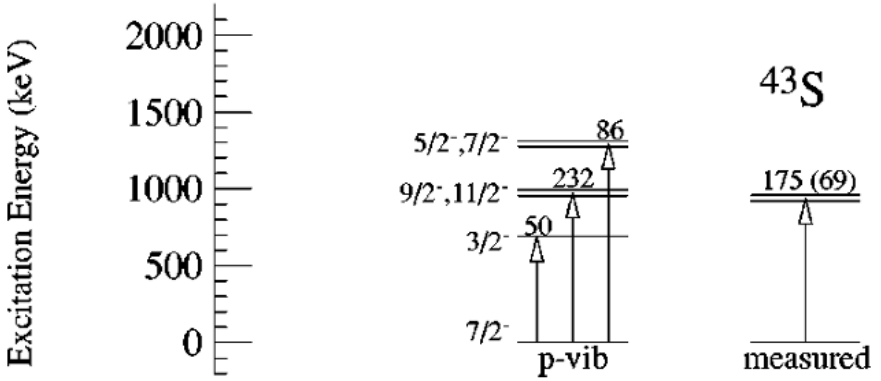
➔**"synthesis skills"? Nonsense. Science isn't about proving how clever we are. It's about showing the steps. The failures. The struggles. The traps to avoid, so others can go further.**



Blaming ChatGPT is like blaming a printer for a plagiarized thesis .
Or a knife for a murder.
The problem is not the tool. The problem is lack of common sense, intellectual laziness, and the mindless pressure to publish anything, anywhere —just to decorate a CV.

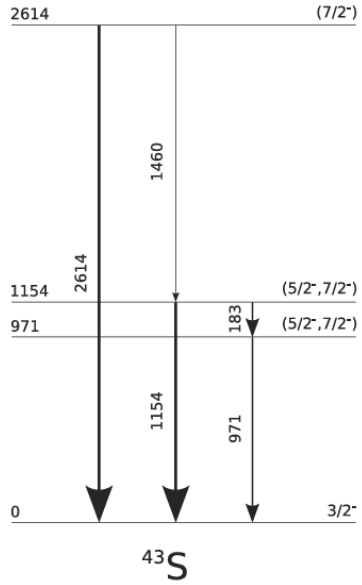
Case Study: When Nothing Works…

^{43}S



Nucleus	E/A (MeV)	E_γ (keV)	$B(E2\uparrow)$ (e^2 fm^4)
^{35}Al	43.8	1006 (19)	142 (52)
^{37}Si	45.1	1437 (27)	101 (45)
^{39}P	46.3	976 (17)	97 (30)
^{41}S	47.4	449 (8)	167 (65)
		904 (16)	232 (56)
^{43}S	42.0	≈940	175 (69)
^{45}Cl	43.0	929 (17)	87 (24)

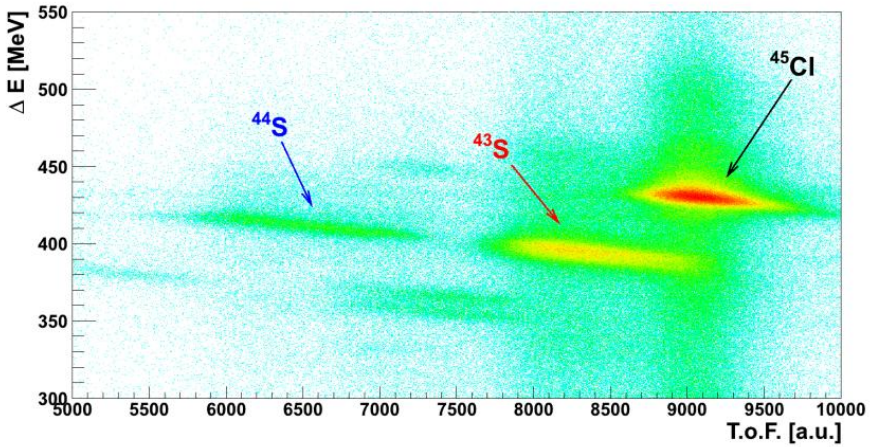
R. Ibbotson et al., Phys. Rev. C 59, (1999)

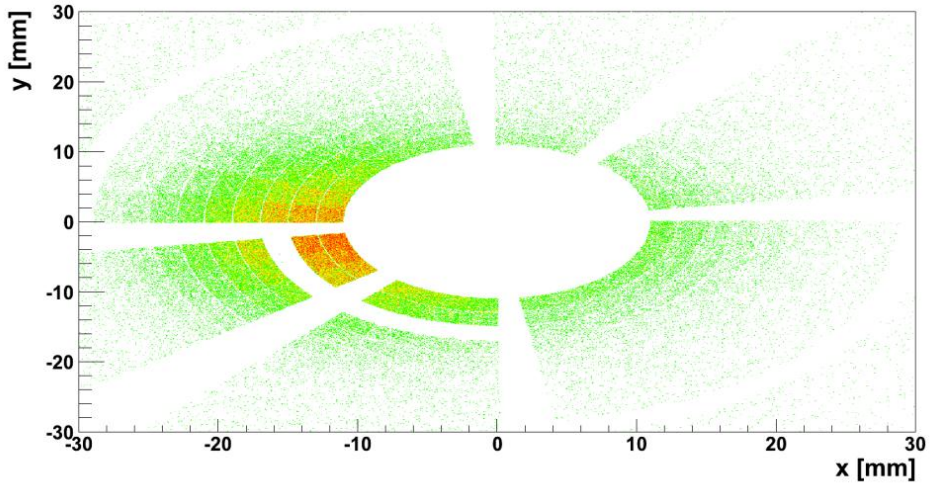


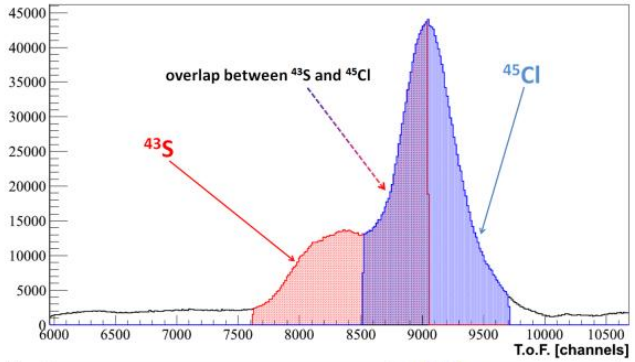
E_{level} [keV]	E_γ [keV]	I_γ^{knock} [%]	I_γ^{frag} [%]	BR [%]	σ [mb]
971(6)	971(6)	56(4)	62(17)	0.4(10)	0.3(8)
1154(7)	1154(7)	100	100	19(2)	15(1)
	183(1)	53(3)	58(12)		
2614(9)	2600(16)	98(7)	–	13(2)	10(1)

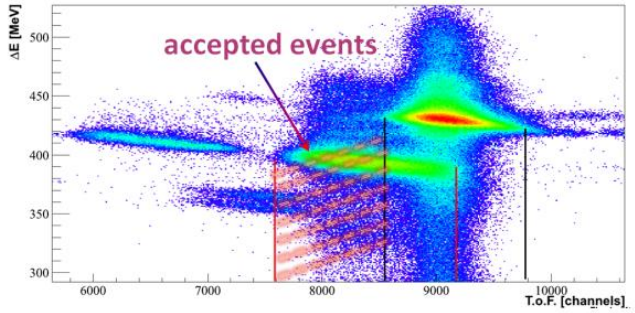
L.A. Riley et al., Phys. Rev. C. 80, 037305 (2009)

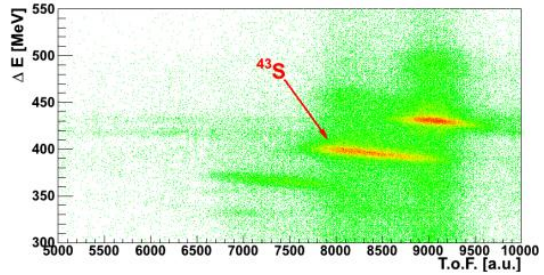
Case Study: When Nothing Works…

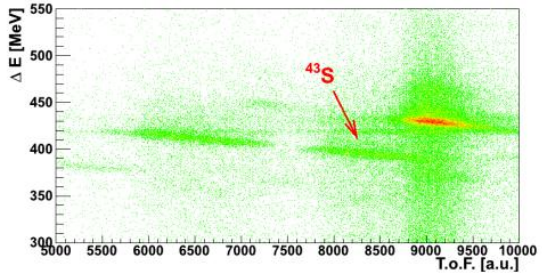


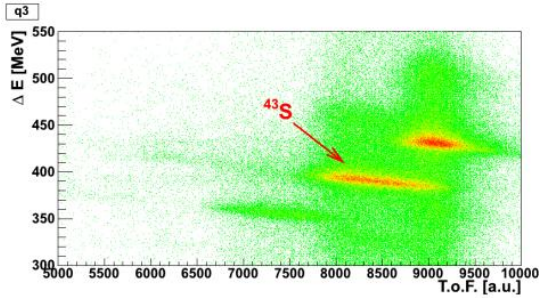


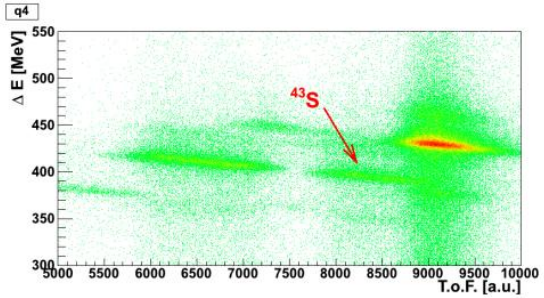




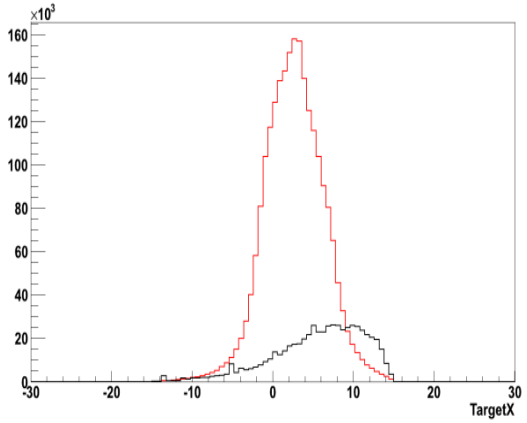


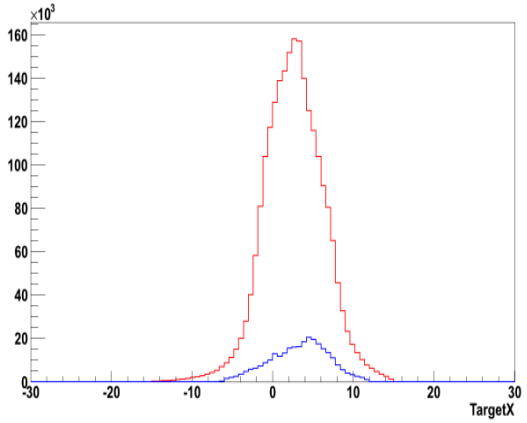


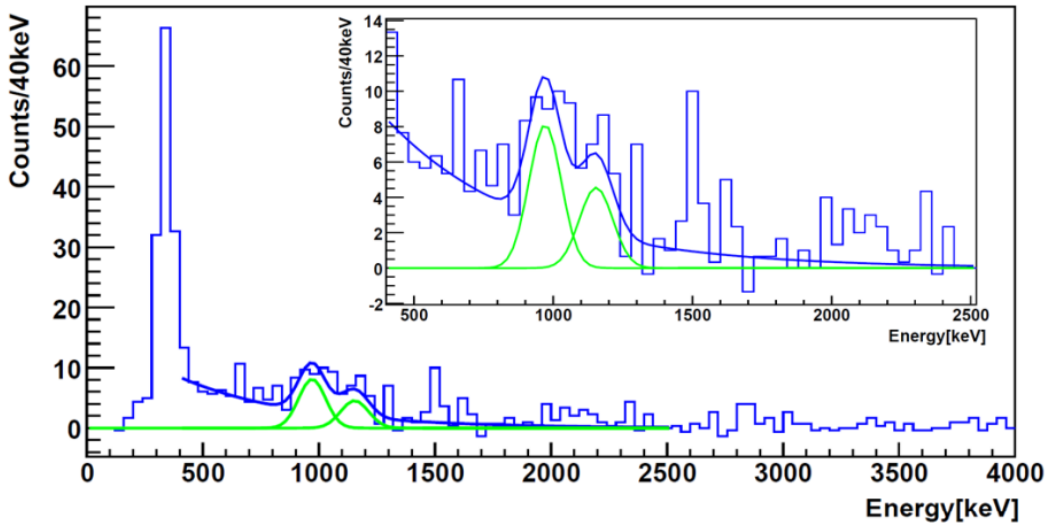




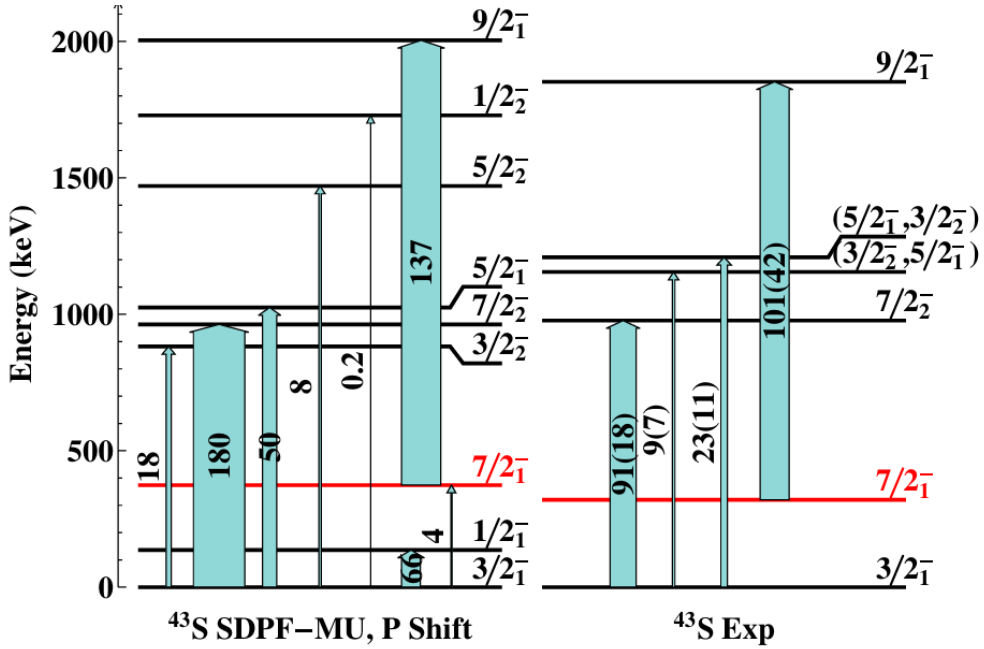
Case Study: When Nothing Works…







The fit procedure described above returned for the peak at the energy of 971 keV a number of counts of 29(9), while for the peak at the energy of 1154 keV the number of counts extracted was 21(7). Introducing these numbers in the formula for the extraction of the B(E2), results a value of **55(24)** e^2fm^4 for the level at 971 keV, and a B(E2) = 182(34) e^2fm^4 for the one at the energy 1154 keV.



B. Longfellow et al., PRL, 125, 232501 (2020)

R. Ibbotson ➔approx 175(69) e^2fm^4

From Virtual Photons to Nuclear Deformation: The Harsh Elegance of Coulomb Excitation

Coulomb excitation has proven invaluable in advancing our understanding of nuclear structure, particularly for exotic systems:

- ✓ Mapping the onset of collectivity across isotopic chains (e.g., N=40, N=60, N=82).
- ✓ Probing shape coexistence via B(E2) values to multiple 2^+ states (e.g., ^{100}Zr, ^{72}Kr).
- ✓ Identifying shell closures and erosion (e.g., quenching of collectivity beyond magic numbers).
- ✓ Benchmarking effective charges and shell-model interactions.

Modern advances:

- ✓ High-resolution tracking.
- ✓ Segmented gamma arrays.
- ✓ Access to rare isotopes (few pps).

Complementarity with Lifetime Measurements

- ✓ Coulomb excitation provides direct access to transition probabilities via cross-section measurements.
- ✓ Lifetime techniques (DSAM, RDM) offer independent determination based on decay time.

Coulomb excitation:

- ✓ Best for short-lived exotic beams.
- ✓ Clean EM selectivity.

Lifetime methods:

- ✓ Use thick targets or plunger devices.
- ✓ Limited to ps–ns lifetime range.

Together, they:

- ✓ **Cross-validate results.**
- ✓ **Increase confidence in B(E2) extraction.**

THANK YOU!