GOSIA calculations
[exercises]

gosia < sample.inp

Manual: www.slcj.uw.edu.pl/gosia

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Before you start

- Do the **research**: what do you know about the isotope of interest: go through the data base, check the **level scheme**, look for known **lifetimes**, **branching ratios**, B(E0,E1,E2,E3..), B(M1), **mixing ratios, quadrupole moments**. If you are lucky and you find some spectroscopic data for your nucleus, recalculate the transition strengths into matrix elements. Read the papers. If something is evaluated in the data basis as an average value it doesn't mean it is the value you should use!
- **Ask theorists!**
- http://bricc.anu.edu.au/ - **electron conversion coefficient** calculator
- Calculate the **SAFE energy**
- What is the **beam**? Be sure about the energy and scattering angles
- What is the **target**? How thick? How complex? Energy loss of the beam in the target material is important (ELO, SRIM programs)
- **Normalization** method: known target excitation or lifetimes?
- **Detectors**:
  - **Gamma array:** how many? How far from the target? Material? Size? Efficiency?
  - **Particle array:** theta and phi angles, the geometry (CD, PIN, MCP...), dead pixels, useful detection range?

GOSIA input structure

1. OP,FILE – header files (TAPEs)

2. OP,TITL

3. OP,GOSI (with fit) - OP,COUL (without fit)

- LEVE

- ME

- EXPT

- CONT

END,

4. OP,YIEL

5. OP,RAW

6. OP,INTG/INTI

7. OP,MINI

8. OP,ERRO

9. OP,POIN

10. OP,STAR

11. OP,THEO

12. OP, MAP

13. OP, REST

14. OP,GDET

15. OP,SIXJ

GOSIA input file: OP,FILE

22 3 1	
mini.out	← Output file name
9 3 1	
gdet.f9	← OP,GDET output
8 3 1	
gdet.f8	← OP,GDET (if OP,RAW used)
12 3 1	
matrix.me	← Matrix elements
3 3 1	
yield.f3	← Gamma yields
4 3 1	
corr.f4	← Corrected gamma yields (after OP,INTG / INTI)
7 3 1	
map.f7	← OP,MAP output
14 3 1	
sixj.14	← OP,SIXJ output (if this option used)
0 0 0	

GOSIA input file: OP,GDET

```
OP,FILE
22 3 1
gdet.out
9 3 1
gdet.f9
8 3 1
gdet.f8
0 0 0
OP,TITL
Gamma detectors
OP,GDET
-1
0 9.5 14.0 22
0 0 0 0 0 0 0
OP,EXIT
```

- 22 3 1 / gdet.out — output name
- 9 3 1 / gdet.f9 — GDET output file – parameters needed to reproduce γ energy dependence of the gamma detector solid angle attenuation coeff. Q_k
- 8 3 1 / gdet.f8 — GDET output file – absorption coeff. needed to reproduce the detector efficiency, created if NPD is **negative** – related to “raw” spectra defined in OP,RAW
- 0 0 0 — End of OP,FILE
- OP,TITL / Gamma detectors — Title
- OP,GDET block — OP,GDET input options

```
OP,GDET
-2
0  9.5  14.0  22     !det1
0 0 0 0 0 0 0
0  9.5  14.0  22     !det2
0 0 0 0 0 0 0
OP,EXIT
```

NPD – number of **physically different** gamma detectors in use for all experiments defined in EXPT

“-” for OP,RAW

The distance from the target [cm]

The thickness of the Al absorber

The length of a crystal [cm]

The radius of the active core

The radius of the inactive core

GOSIA input file: OP,GOSI

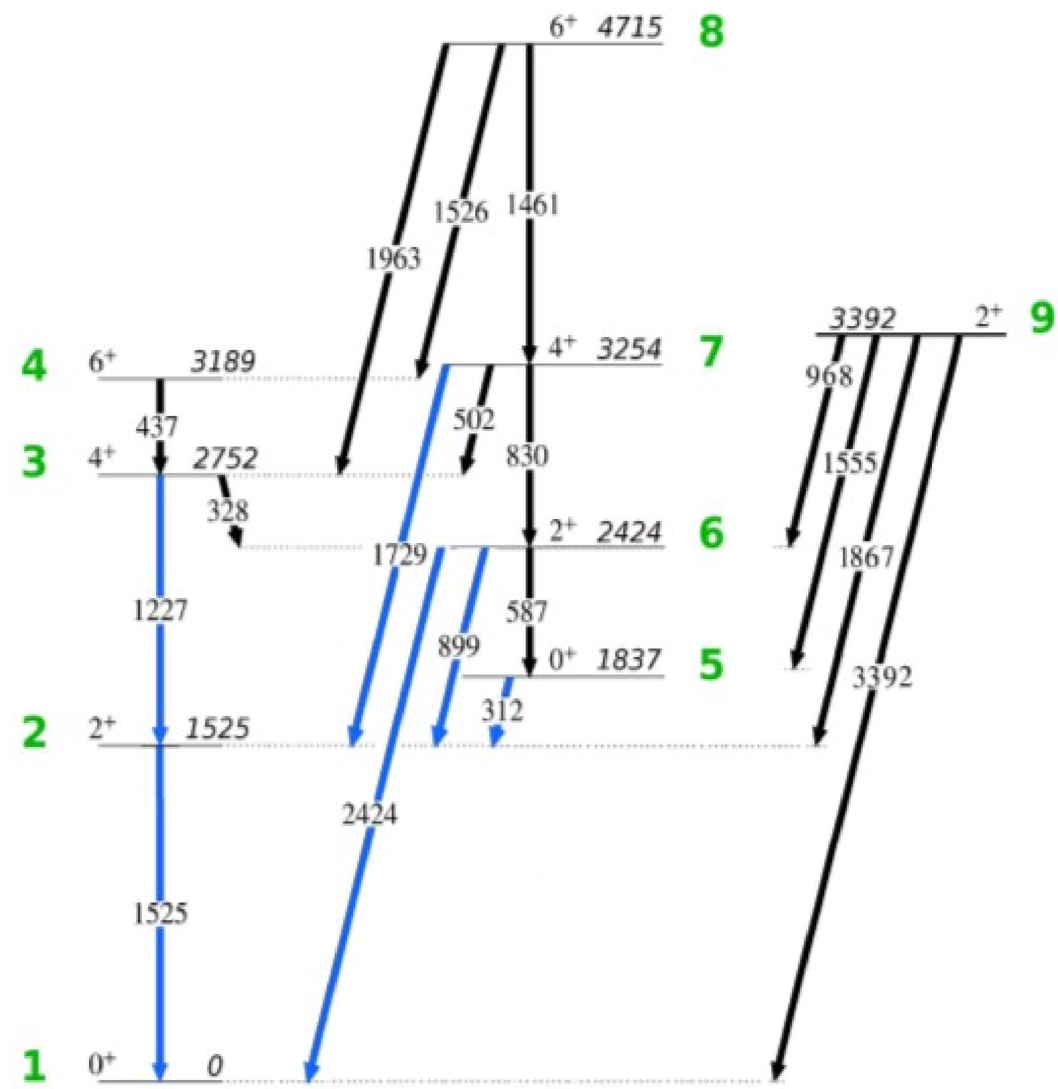
LEVE
1 1 0 0.0
2 1 2 1.525
3 1 4 2.752
.
.
.
0 0 0 0

Level INDEX

Parity

SPIN

E [MeV]



1 = GROUND STATE

GOSIA input file: OP,GOSI

```
ME
2 0 0 0 0
  1  2 0.20   0.0001  1.5
  2  6 0.08   -1.5     1.5
  .
  .
7 0 0 0 0
  2 6 1.01   -2.       2.
  .
  .
0 0 0 0 0
```

INDEX1

INDEX2

ME

Limits for ME
(R1 and R2)

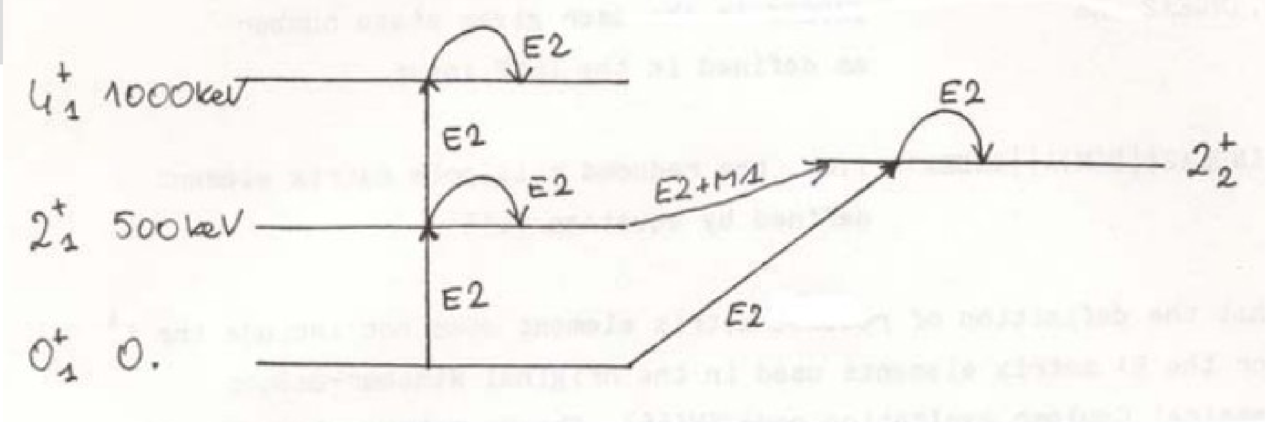
Multipolarity E(M)λ:
1 E1
2 E2
3 E3
..
7 M1
8 M2

< INDEX1 || E(M)λ || INDEX2 > **[eb]**

INDEX1 and INDEX2 are given in increasing order (start with INDEX1)

If "-" used before INDEX2 → COUPLING

2 -6 0.08 1 2



We need a set of ME to start with

levels.inp

```
1 1 0 0.0
2 1 2 0.413
3 1 4 1.005
4 1 0 0.825
5 1 2 0.881
6 1 4 1.208
0 0 0 0
```

Level E[MeV]

SPIN

Parity

Level number

megen levels.inp

```
1
Create setup for this multipolarity (y/n)
n
2
Create setup for this multipolarity (y/n)
y
Do you want them coupled ?
n
Please give limit value
-1.5 1.5
3
Create setup for this multipolarity (y/n)
n
(...)
7
Create setup for this multipolarity (y/n)
y
Do you want them coupled ?
n
Please give limit value
-1 1
8
Create setup for this multipolarity (y/n)
n
```

E2

M1

We need a set of ME to start with

levels.inp

```
1  1  0  0.0
2  1  2  0.413
3  1  4  1.005
4  1  0  0.825
5  1  2  0.881
6  1  4  1.208
0  0  0  0
```

Level E[MeV]

SPIN

Parity

Level number

me.out

```
2 0 0 0 0
  1  2 1   1.5  -1.5
  1  5 1   1.5  -1.5
  2  2 1   1.5  -1.5
  2  3 1   1.5  -1.5
  2  4 1   1.5  -1.5
  2  5 1   1.5  -1.5
  2  6 1   1.5  -1.5
  3  3 1   1.5  -1.5
  3  5 1   1.5  -1.5
  4  5 1   1.5  -1.5
  5  5 1   1.5  -1.5
  5  6 1   1.5  -1.5
  6  6 1   1.5  -1.5
 7 0 0 0 0
  2  2 1   1.0  -1.0
  2  5 1   1.0  -1.0
  3  3 1   1.0  -1.0
  3  6 1   1.0  -1.0
  5  5 1   1.0  -1.0
  6  6 1   1.0  -1.0
 0 0 0 0 0
```

E2

initial level | final level | starting value (1) | low limit | high limit

M1

OP,THEO - COLLECTIVE MODEL ME

- generates the ME from rotational model
- generates only the matrix specified in the ME input and writes them to the output file
- For **in-band or equal-K** interband transitions only one intrinsic moment for a given multipolarity marked **Q1** is relevant.
- For **non-equal-K** values generally two moments with the projections equal to the **sum and difference of K's** are required (**Q1 and Q2**), (unless one of the K's is zero, when again only Q1 is needed)
- For the **K-forbidden** transitions a three parameter Mikhailov formula is used.

OP,THEO - COLLECTIVE MODEL ME

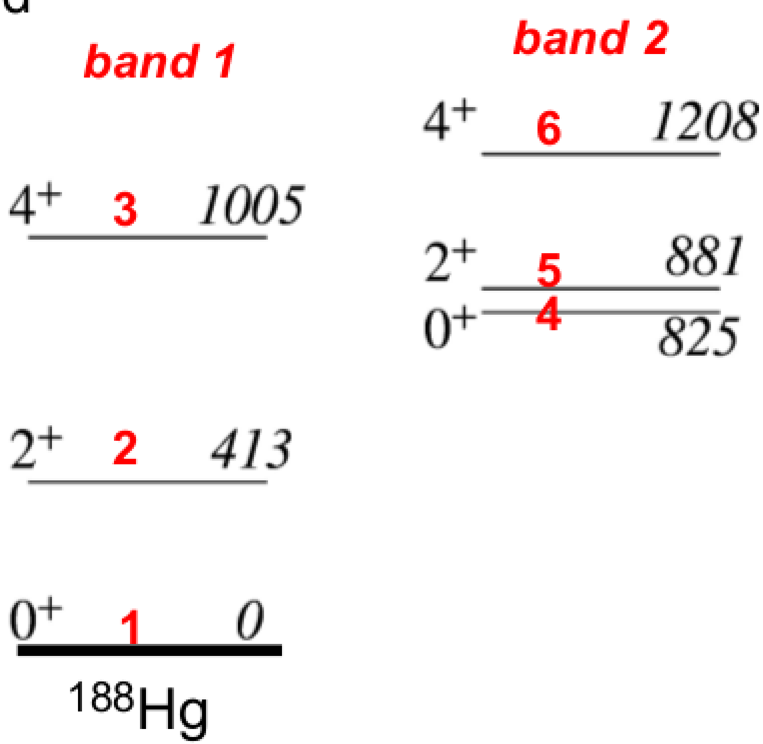
OP,THEO	
2	Two bands
0,3	K of the gsb, # of levels
1,2,3	Level list for the gsb
2,3	K of the gamma band, # of levels
4,5,6	Level list for the gamma band
2	Multipolarity E2
1,1	In-band, gsb
1,0,0	Q1, two zeros irrelevant
1,2	Interband E2
1,1,0	Q1,Q2- Mikhailov formula, none of the K's=1/2, so Q3 irrelevant
2,2	In-band, gamma band
1,0,0	In-band Q1, Q2 and Q3 irrelevant
0,0	Ends E2 loop
7	M1 loop
1,2	Interband M1
1,1,0	Q1 and Q2 for Mikhailov formula
2,2	In-band M1
1,0,0	Q1 for in-band transitions
0,0	Ends M1 loop
0	Ends multipolarity loop and OP, THEO input

OP,THEO for ^{188}Hg (EXAMPLE)

$$\langle KI_f \| \hat{M}(E2) \| KI_i \rangle = \sqrt{(2I_i+1)}\langle I_i, K, 2, 0 \mid I_f K \rangle \sqrt{\frac{5}{16\pi}} eQ_0$$

```
OP,THEO
2
0,3
1,2,3
0,3
4,5,6
2
1,1
Q1,0,0
1,2
Q1,0,0
2,2
Q1,0,0
0,0
0
```

- 2 — number of bands (2)
- 0,3 — First band, K and number of states
- 1,2,3 — band member indices
- 0,3 — Second band, K and number of states
- 2 — Multipolarity E2
- 1,1 — Bands 1 and 1 (in-band)
- Q1,0,0 — Moment Q1 of the rotational band
- 0,0 — end of multipolarities loop
- 0 — end of band-band input



Courtesy: K. Wrzosek-Lipska

GOSIA input file: OP,GOSI: EXPT

EXPT

NEXP Z1 A1

+/-Z2 A2 Ep +/-θ_{proj} Mc Ma IAX φ1 φ2 IKIN LN

- NEXP – Number of experiments
- Z1 A1 – Charge and mass number of investigated nucleus
- +/-Z2 A2 – Charge and mass number of uninvestigated nucleus: "+" for target excitation, "-" for proj. excitation
- Ep – Mean values of beam energy [MeV]
- +/-θ_{proj} – Mean values of scattering angle: "+" projectile, "-" recoil
- Mc Ma – Controls of magnetic substates
- IAX – Axial symmetry flag: 0 – yes, 1 – no
- φ1 φ2 – Min and max **φ** angle
- IKIN – Kinematic flag: 0 - backward $\boldsymbol{\theta}_{CM}$, 1 - forward $\boldsymbol{\theta}_{CM}$
- LN – Normalization flag

EXPT

2 20 42

-79 197 167 122 3 1 1 -170 172 0 1

-82 208 167 122 3 1 1 -170 172 0 2

^{42}Ca beam on ^{197}Au and ^{208}Pb targets

GOSIA input file: OP,YIEL

```
OP,YIEL
0
5 2
0.1 0.3 0.5 1.0 1.5
1
0.000829  2.41E-5  5.60E-6  1.143E-6  0.000269
2
0.01175   0.0001328  2.06E-5  2.59E-6  8.94E-5  0.000314
5 2
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
2 1
1                                       !EXP1
0.001 0.001 0.001 0.001 0.001
1 1 1 1 1
1                                       !EXP2
0.001 0.001 0.001 0.001 0.001
1 1 1 1 1
3
```

GOSIA input file: OP,YIEL

```
OP,YIEL
0
5 2
0.1 0.3 0.5 1.0 1.5
1
0.000829  2.41E-5  5.60E-6  1.143E-6  0.000269
2
0.01175   0.0001328  2.06E-5  2.59E-6  8.94E-5  0.000314
5 2
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
1  2  3  4  5
25  55  85   130  172
40  75  270 325  59
2 1
1                                    !EXP1
0.001 0.001 0.001 0.001 0.001
1 1 1 1 1
1                                    !EXP2
0.001 0.001 0.001 0.001 0.001
1 1 1 1 1
3
```

Electron conversion coefficients (BRICC)

number of energies and multi-polarities
Energy points [MeV]
Mult. 1
Coeff. for each energy point
Mult. 2
Coeff. for each energy point

Total number of gamma detectors for each exp
Numbers of gamma det. in GDET, exp 1
Θ, exp 1
Φ, exp 1
Numbers of gamma det. in GDET, exp 2
Θ, exp 2
Φ, exp 2

NORMALIZATION transition

Number of data sets for exp. 1
Upper limits for all gamma det in exp 1
Relative normalization factors for each det. In exp 1

NTAP (0 for OP,POIN, OP,STAR, 3 if OP,CORR after integration is used, 4 if OP,MINI and ERRO is used)

GOSIA input file: OP,YIEL

```
2    1.0
     4 5 4 2   0.007   0.003
     5 1 5 2   0.34    0.02
2    1.0
     2     1.19  0.04
     3     4.45  0.10
1    1.0
     6 2  -0.18     0.02
1    1.0
     2  2  2    -0.25  0.051
```

Number and weight of known branching ratios:
Transition 1 (I2, I1), Transition 2 (I2, I1), BR, ΔBR

Number and weight of known mean lifetimes [ps]
Level index, τ, Δτ

Number and weight of of known δ(E2/M1) mixing
Transition, δ, Δδ

Number and weight of of known matrix elements
multipolarity, I1, I2, ME, ΔME

```
0 0
0 0      in case nothing is known
0 0      about the investigated nucleus
0 0
```

YIELD definition

POINT

- **<u>One</u>** energy (E)
- **<u>One</u>** angle (Θ)

  as defined in EXPT

  use **OP,POIN**

INTEGRATED

- Energy **<u>range</u>**

  (E_{min}-E_{max})
- Angular **<u>range</u>**

  (Θ_{min},φ_{min} – Θ_{max},φ_{max})

  as defined in **OP,INTG / INTI**

Matrix elements values, excitation probability

TAPE 3 / 4 (experimental yields)

IEXP – exp. number – the same order as in EXPT andOp,YIEL

1 1 20 42 167 3 1.0

5 2 88 10

3 2 500 20

2 1 11000 100

NG – number of data sets for exp. IEXP (NDST in OP,YIEL)

ZP – proj. charge number

AP – proj. mass number

EP – proj. bombarding energy [MeV]

ND - of γ-rays for the specific IEXP and data set

WT - Weight

Ii – initial level index

If – final level index

Y – γ-ray yield

ΔY – absolute error of γ-ray yield

1 1 20 42 167 3 1.0

5 2 88 10

3 2 500 20

2 1 11000 100

GOSIA input file: OP,POIN

- **NTAP = 0** in OP,YIEL
- This option evaluates the point gamma yield in the laboratory frame for the $I_i \rightarrow I_f$ transition for **one energy** and **one particle scattering angle** given in **EXPT**

$$Y^{Point}(I \rightarrow I_f) = \sin(\theta_p) \int_{\phi_p} \frac{d^2\sigma(I \rightarrow I_f)}{d\Omega_\gamma d\Omega_p} d\phi_p$$

- includes the **Rutherford cross section**, the sin(Θ) term, integration over the projectile φ scattering angle, the deorientation effect and gamma-detector attenuation coefficients (from OP,GDET)
- Calculates the yield for one system – defined as one **θ-E** point
- We use OP,POIN after OP,YIEL

0 – simulation, but not in use
1 – "real" calculations, we use this option

OP,POIN
YFL YLIM

1 0

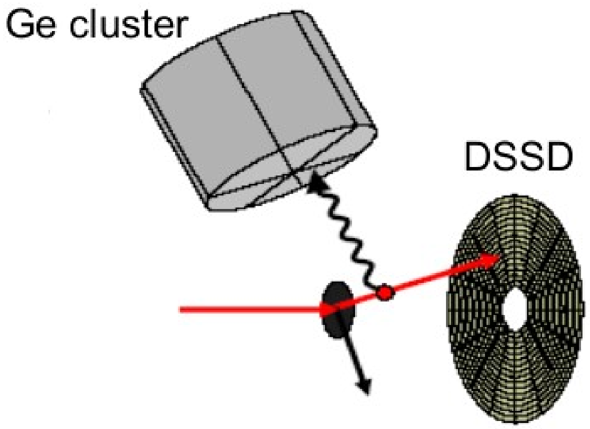
If **IFL=1** – if the transition specified in TAPE3 normalized to norm. transition in OP,YIEL exceed it, it is treated like the experimental observable and stored on TAPE4

- We use REAL detectors with continuous dimensions

Why INTEGRATION?

- REAL conditions - GOSIA calculates **yields** from ME to get **realistic comparison** with experimental data
- integration over **solid angle** of the particle detectors, **energy loss in the target,** full correction for the velocity of the deexciting nucleus and the **deorientation effect** is included
- the Rutherford scattering is integrated over the particle detectors and energy loss in the target – an absolute normalization.
- the '**GOSIA yield**' may be understood as a mean differential cross section multiplied by a target thickness (in mg/cm^2)

$[Y] = [mb/sr] \times [mg/cm^2]$



GOSIA input file: OP,INTG

2 stages:

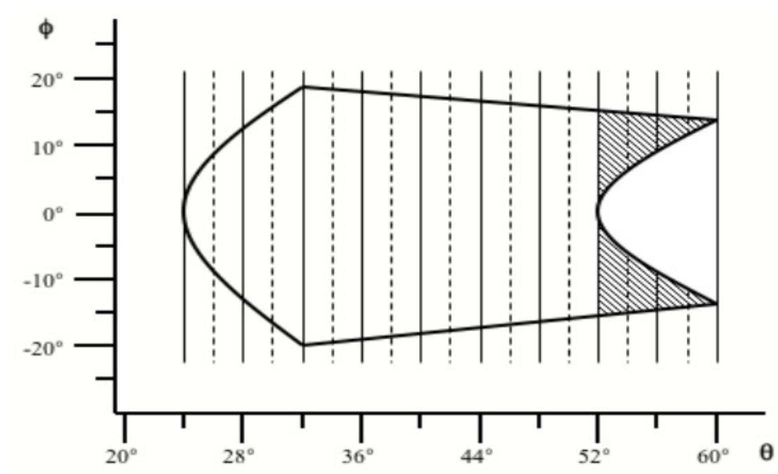
- γ yields integrated over azimuthal angle **φ** for each energy **E** and center-of-mass scattering angle **θ** meshpoint (stored as an external array). The calculation of the meshpoint yields is repeated for each experiment (**as declared in EXPT**)

- integrate over bombarding energy **E** and the range of scattering angles **θ** of the particle detectors which is performed by **interpolating** between the yields calculated at each **E-θ** meshpoint

(*axial sym., circular detectors option recommended)

OP,INTG
NE +/-NT E_{min} E_{max} θ_{min} θ_{max}
E_1 E_2 ... E_{NE}
$+/-\theta_1$ $+/-\theta_2$ ... $+/-\theta_{NE}$
NFI
φ_1 φ_2 ...
NP
E_1 E_2 ... E_{NP}
$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$
NI_1 NI_2

CONT
SPL,1. - SPILINES
END,



GOSIA input file: OP,INTG

OP,INTG

NE +/-NT E_{min} E_{max} θ_{min} θ_{max}

Total number of E meshpoints, θ meshpoints ("-" when the (θ,φ) shape will be defined), Integration limits: minimum and maximum bombarding E [MeV] , minimum and maximum LAB angle of detected particle (in degrees)

E_1 E_2 ... E_{NE}

Energy meshpoints (COULEX calculation performed for points)

$+/-\theta_1$ $+/-\theta_2$ ... $+/-\theta_{NE}$

Projectile scattering θ meshpoints (COULEX calculation performed for points)

NFI

Number of φ ranges for θ_i meshpoint - for θ(φ) dependence (repeat for each θ)

φ_1 φ_2 ...

NFI pairs of φ for θ_i meshpoint (repeat for each θ_i)

NP

Number of stopping power (3<NP<20). If NP=0, values are taken from prev. exp.

E_1 E_2 ... E_{NP}

Energy meshpoints in [MeV] for the stopping powers

$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$

Stopping powers in [MeV/(mg/cm^2)]

NI_1 NI_2

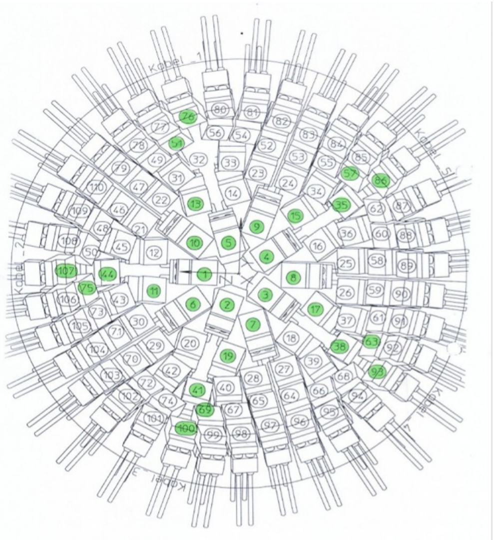
Number of subdivisions in E (NI1) and projectile scatt. angle (NI2) used during the integration. EVEN and less than 100 both.

GOSIA input file: OP,INTG - circular

Intensities **for each Ge detector – circular particle detector option (with PIN diodes)**

Calculate the Δφ at each subdivision of θ (**CONT CRD,#exp**)
Circular det. approximation for PiN diodes (**CONT PIN,#PIN**)

OP,INTG
NE +/-NT E_{min} E_{max} θ φ $θ_{1/2}$
E_1 E_2 ... E_{NE}



```
OP,INTG
7    3    146. 152.    123.9    242.32    4.4 ! PIN6
146 147 148 149 150 151 152
7    3    146.  152.    123.9    298.28    4.4 ! PIN62
146 147 148 149 150 151 152
7    3    140.  152.    123.9    226.27    4.4 ! PIN68
146 147 148 149 150 151 152
7    3    140.  152.    123.9    98.32     4.4 ! PIN75
146 147 148 149 150 151 152
...
```

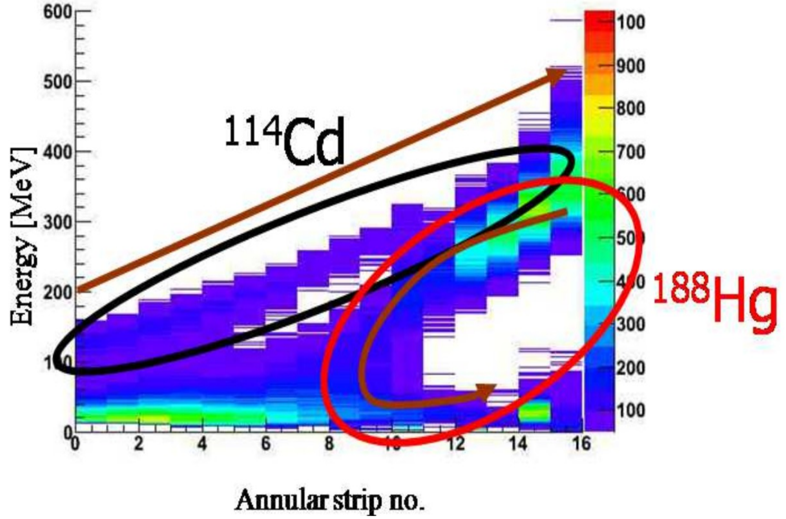
```
CONT
SMR,
LCK,
0,0
INR,
SPL,1.
CRD,1.
1
PIN,1.
1,44
PRT,
4,0
2,0
13,0
14,0
16,0
5,1
12,0
18,1
0,0
END,
```

GOSIA input file: OP,INTI

Developed to handle problems that occur for integration of systems involving inverse kinematics and when the **recoiling target nucleus is detected** (2 kinematic solution).

For each beam E and each angle the subroutine INVKIN calculates the appropriate value of kinematic flag and set it **automatically**

Θ angles always positive and correspond to laboratory scattering angles of the **detected particle**, that is, the angle of the scattered projectile if it is detected and the angle of the recoiling target nucleus if it is detected.



N. Bree, PhD thesis, KULeuven,

OP,INTI
NE +/-NT E_{min} E_{max} θ_{min} θ_{max}
E_1 E_2 ... E_{NE}
θ_1 θ_2 ... θ_{NE}
NFI
φ_1 φ_2 ...
NP
E_1 E_2 ... E_{NP}
$(dE/dx)_1$ $(dE/dx)_2$ … $(dE/dx)_{NP}$
NI_1 NI_2

```
OP,INTI                    !for axial sym. and circ. det.
8 9 226 240 133 168
226 228 230 232 234 236 238 240
133 135 140 145 150 155 160 165 168
8
226 228 230 232 234 236 238 240
12.2 12.17 12.13 12.10 12.05 12.00 11.90 11.80
20,20
```

YIELD correction

- Minimization of is usually performed using **corrected** yields
- Correction depends on the set of ME: GOSIA calculates the **point** yield ($\mathbf{Y_p}$) and the **integrated** yield ($\mathbf{Y_I}$) from the ME and gives the **correction factors CF** for each experimental yield (**OP,CORR** needed):

$$CF = \frac{Y_P}{Y_I} \longrightarrow Y^c_{exp} = Y_{exp} \cdot CF$$

After minimization the correction procedure should be repeated with a new set of ME (better fit, different correction) → until the solution is converged

- CF are calculated for **each** experimental yield

^{42}Ca on ^{197}Au

E_{av} = 167 MeV

Θ_{av} = 122^o

EXPERIMENT 2 DETECTOR 1

NI	NF	YEXP	YCOR	COR.F
3	2	.112E+00	.113E+00	.101E+01
6	1	.380E-01	.374E-01	.984E+00
6	2	.106E+00	.102E+00	.966E+00
5	2	.854E+00	.822E+00	.962E+00
2	1	.124E+02	.120E+02	.969E+00

GOSIA AS A SIMULATION TOOL: YIELD ⇒ COUNT RATE

$$Counts = 10^{-27} \cdot \left[\frac{Q}{\hat{q}e}\right] \cdot \left[\frac{N_A}{A}\right] \cdot [\rho dx] \cdot \quad \textbf{Yintg} \quad \cdot \Delta\theta_p \cdot \varepsilon_p \cdot \varepsilon_\gamma \cdot \Delta\Omega_\gamma$$

where:

Q is the integrated beam charge $[C]$

$\hat{q}$ the average charges state of the beam

e the proton charge $[1.602 \times 10^{-19} C]$

N_A Avogadro number $[6.022 \times 10^{23} atoms/mol]$

A Target mass number $[g/mol]$

ρdx areal target thickness in $[g/cm^2]$

Yintg from INTG or INTI $[\frac{mb}{sr \cdot rad}]$

$\Delta\theta_p$ Projectile scattering angle range $[rad]$

ε_p particle detection efficiency per unit solid angle

ε_γ γ-ray detector efficiency excluding the geometrical solid angle

$\Delta\Omega_\gamma$ geometrical solid angle of the γ-ray detector. Note that usually one only knows the product $\varepsilon_\gamma \cdot \Delta\Omega_\gamma$

$$\textbf{Count Rate} = \frac{7.6 \times 10^{-6} \times yield \times current[pps] \times eff}{A_{target}}$$

GOSIA input file: OP,RAW

- This option needs energy-dependent efficiency calibration for each individual gamma detector (GREMLIN, EFFIT..)
- the first entry of **OP,GDET** should be **<u>negative</u>** to produce the **TAPE8**
- Need to declare which efficiency parametrization you need! (in **CONT**, flag **EFF**): 0-Gremlin, 1-Jaeri, 2-Fiteff, 3-Leuven, 4-Radware
- **Do not use if all gamma intensities are efficiency-corrected**

```
CONT
EFF,5
1,0
2,0
3,0
4,-1
5,0
END,
```

OP,RAW	
IEXP	number of the experiment (according to the sequence in **EXPT**)
A1 A2 A3 A4 A5 A6 A7 A8	gamma det. Eff. Parametrization, det 1 (as in **OP,GDET**)
A1 A2 A3 A4 A5 A6 A7 A8	gamma det. Eff. Parametrization, det 2
…	
...	
A1 A2 A3 A4 A5 A6 A7 A8	
NC	number of CLUSERS
ID1	number of Ge detectors in cluster 1
I1 I2 … I(ID1)	index numbers of Ge detectors in the cluster
ID2	number of Ge detectors in cluster 2
I1 I2 … I(ID2)	index numbers of Ge detectors in the cluster
...	
…	
0	End of the input

GOSIA input file: OP,MINI

χ2 function minimization

$$\chi^2 = \frac{1}{p}\left\{ \sum_{i=1}^{N\exp} \sum_{j=1}^{N\det} \sum_{k=1}^{N\gamma} \left[\left(\frac{C_{ij} Y_k^{(T)} - Y_k^{(E)}}{\Delta Y_k^{(E)}} \right)^2 \right. \right.$$

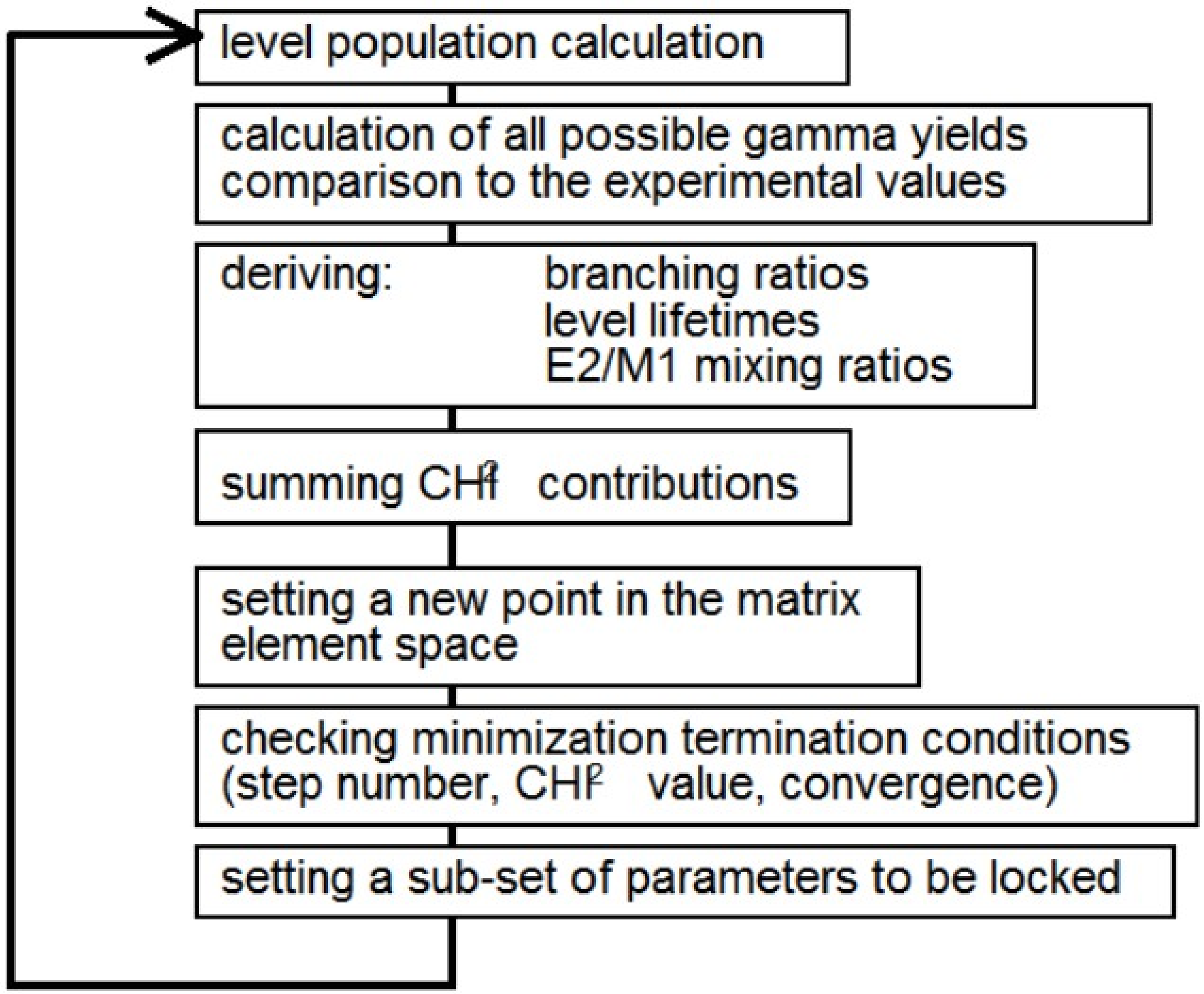
$$\left. + \sum_{i=1}^{Ns.d.} \left(\frac{d_i^{(T)} - d_i^{(E)}}{\Delta d_i^{(E)}} \right)^2 \right\}$$

- experimental yield
- calculated yield
- normalisation factor
- spectroscopic data point
- calculated magnitude

> The fitting procedure is continued, until the convergence of the χ^2 is achieved and the set of matrix elements optimally reproduce the experimental data.

Remember to run OP,MAP before OP,MINI, each time you change something in ME (insert OP,MAP command directly after OP,YIEL). This option stores the **q-parameters** important for **reorientation effect** (effective strength, related to the magnetic substates coupling) on **TAPE7**

GOSIA input file: OP,MINI



GOSIA input file: OP,MINI

IMODE (4 digits):
1-fast approximation, **2**-full COULEX formalism
0-simple steepest descent mini, **1**-gradient mini with gradient derivative mode
0-absolute changes in values of ME will be used to improve the fit, **1**-LOG values of ME used
0- absolute values of spectroscopic data will be used, **1**-LOG values of spectroscopic data

1 – fixes all ME with absolute value of partial derivative is less than DLOCKS

OP,MINI
IMODE IPTL CHILIM CONV TEST LOCKF NLOCK IFBL LOCKS DLOCKS

The limit for LOCKS

max number of mini steps

convergence criterion
$|\overline{ME}_{n+1} - \overline{ME}_{n}| < CONV$

0 – forward difference method,
1 – forward-backward method

Stop criterion

TEST≤1 – recalculation of the internal correction coeff. between fast approx. and full mini.

Number of ME to be locked if LOCKF=1 and CONV fulfilled

0 – mini will be terminated if CONV is fulfilled
1 – fix the NLOCK number of ME with the most significant derivative

```
OP,MINI
2100   20   0.0001   0.0001   1   1   1   1   1   0.0001
OP,EXIT
```

GOSIA input file: OP,ERRO

- for estimating the error bars to be assigned to the set of matrix elements corresponding to the minimum value of χ^2 (**CONT CRF,**), NTAP=4 (OP,YIEL)

MS / MEND:
0 – all ME (excluding fixed ones)
-1 – for ranges of ME (introduced later on)

IFC:
0 – correlation matrix used
1 – correlation matrix not used

IDF – Mode flag:
0 – diagonal
1 – correlated

```
OP,ERRO
IDF   MS   MEND   IREP   IFC   RMAX
```

RMAX – The largest floating point number available on a given computer

IREP – Repetition flag
0 – a new calculation (always for diag. Err.)
1 – read from TAPE15 (for corr. err.)
2 – if Sum Rules TAPE3 was created

- two separate stages:

1. the "diagonal",or uncorrelated errors (calculated individually for each matrix element) and write them on TAPE15

0 MS MEND 0 0 RMAX

2. the "overall", or correlated errors (the total errors which are the widths of projections on each matrix element's axis of the minimum at the $\chi^2 = \chi^2 + 1$ level). (**CONT SMR, for Sum Rules**). TAPE15 must be included as an input, TAPE3 will contain the output of OP,ERRO for program SIGMA (ATTENTION!!)

1 MS MEND 1 1 RMAX